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Pesticides in Tributaries of the St. Lawrence River 1987-1988 Program Report

by

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and

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Pesticides in Tributaries of the St. Lawrence River (including certain CEPA priority list substances)

1987-1988 Program Report

Centre Saint-Laurent

Hydrology and Networks

Quebec Region

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ABSTRACT

Six St. Lawrence tributaries draining basins of intense agricultural activity were monitored during the growing seasons of 1987 and 1988 in order to determine the spacial and temporal variations of certain pesticide concentrations. The rivers under study were the Yamaska, the St. Francois, the Assomption, the St. Regis, the St. Jacques and the Tortue. Each aquatic system was divided into the following compartments: surface waters, suspended particulate matter, bottom sediments and fish. In surface waters, the monitored concentrations of seven pesticides were found to exceed their respective water quality guidelines (WQG) for the protection of aquatic life. This group was made up of two herbicides, atrazine and 2,4-DP and five insecticides, lindane, endosulfan, diazinon, p,p'-DDE and p,p'-DDT. In the 1987 -1988 sampling seasons, the following numbers of samples exceeded the WQG for the listed pesticides (from a total of 63 samples): atrazine, 21; 2,4-DP, 1; lindane,7; endosulfan, 4; diazinon, 23; p,p'-DDE, 3 and p,p'-DDT, 3.

The atrazine, diazinon and lindane concentrations exceeded their respective guidelines (2.0, 0.08 and 0.01 ug L^{-1}) in three or more of the rivers sampled. The maximum concentrations for atrazine and diazinon were 20.7 and 28.3 ug L^{-1}, respectively. Both of these detections were found in the St. Regis River in June of 1988. The maximum concentration of lindane, 9.58 X 10^{-2} ug L^{-1}, was found at the Assomption River mouth also in June of

1988.

Pesticide loading into the St. Lawrence River was calculated for two rivers, the Yamaska and the Assomption. The maximum loading of atrazine residues from the Yamaska River into the St. Lawrence was found to be at a rate of 0.29 g s^{-1} or 25 kg per day, while for lindane, from the Assomption, maximum loadings of 0.029 g s^{-1} or 2.5 kg per day were calculated.

Generally pesticides were not found in other compartments of the aquatic systems at the concentration ranges apparent in surface water, although many were detected. The pesticides most commonly found in the sediments and fish were the more persistent organochlorines such as α-BHC, cis- and trans-chlordane and DDT and its metabolites.

Several hydrometric and physicochemical parameters of the river systems were monitored concurrently with the pesticides. Pesticide/parameter correlations were carried out and the ensuing relationships discussed.

RESUME

Six tributaires du fleuve Saint-Laurent drainant des bassins agricoles à activité intense ont été surveillés pendant les saisons de croissance de 1987 et 1988 pour déterminer les concentrations et les variations spatio-temporelles des pesticides dans l'eau. Les rivières étudiées ont été la Yamaska, la Saint-François, l'Assomption, la Saint-Régis, la Saint-Jacques, et De la Tortue. Ces systèmes aquatiques ont été subdivisés en différentes composantes soit l'eau de surface, les particules en suspension, les sédiments de fond et les poissons. Dans les eaux de surface, sept pesticides dépassaient leur ligne directrice (LD) respective pour la protection de la vie aquatique. Ces pesticides comprenaient deux herbicides soit l'atrazine et le 2,4-DP, et cinq insecticides soit le lindane, l'endosulfan, le diazinon, le p,p'-DDE et le p,p'-DDT. Pendant les saisons 1987 et 1988, les nombres d'échantillons qui dépassaient les LD pour les pesticides (pour un total de 63 échantillons) sont: atrazine, 21; 2,4-DP, 1; lindane, 7; endosulfan, 4; diazinon, 23; p,p'-DDE, 3 and p,p'-DDT, 3.

L'atrazine, le diazinon et le lindane ont dépassé leur ligne directrice (2,0, 0,08 et 0,01 ug L^{-1}, respectivement) dans au moins trois des rivières échantillonnées. Les concentrations maximales d'atrazine et de diazinon étaient de 20,7 et 28,3 ug L^{-1}, toutes deux dans la rivière Saint-Régis. Une concentration maximale de 0,0958 ug L^{-1} pour le lindane a été mesurée dans la

rivière l'Assomption.

Nous avons calculé l'apport au fleuve Saint-Laurent de deux pesticides, l'atrazine et le lindane à l'intérieur de deux rivières soit la Yamaska et l'Assomption, respectivement. En provenance de la Yamaska, l'apport au fleuve Saint-Laurent de l'atrazine était de 0.29 g s^{-1} (25 kg $jour^{-1}$) et le taux du lindane en provenance de l'Assomption de 0.029 g s^{-1} (2.5 kg $jour^{-1}$).

En général, les pesticides n'ont pas été trouvés dans les autres composantes des systèmes aquatiques aux mêmes concentrations que dans les eaux de surfaces, mais plusieurs ont été détectés. Parmi ceux-ci on retrouve les pesticides plus persistants comme les organochlorés dont le α-BHC, les cis- et trans-chlordane et le p,p'-DDT.

Quelques paramètres physicochimiques de ces rivières ont été mesurés en même temps que les pesticides. Ceci a permis de faire des corrélations entre les paramètres physicochimiques in situ et les pesticides. Les détails de ces corrélations sont discutés dans ce rapport afin d'élucider le mode de dispersion des pesticides.

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LIST OF ABBREVIATIONS

AI	active ingredient
approx.	approximately
A1, A2	upstream sampling sites
°C	degree celsius
CEPA	Canadian Environmental Protection Act
cm	centimetre
g	gram
GWP	Groundwater Pollution (from McRae, 1989)
Kg	kilogram
Koc	soil organic carbon partition coefficient
Kow	octanol-water partition coefficient
L	litre
l.	latitude
lo	longitude
m	meter
mc/s	meters cubed/second
mg	milligram
min	minute
ml	millilitre
mm	millimetre
mPa	millipascal
nd	not detectable
NO2-NO3	nitrite-nitrate
PO4	phosphate
r	correlation coefficient
s	second
SPM	suspended particulate matter
SR	Spearman Rho
ug	microgram
ul	microlitre
U.S. EPA	United States Environmental Protection Agency
vs	versus
WQB	Water Quality Branch
WQG	Water Quality Guideline
α	alpha
β	beta
γ	gamma

1.0 INTRODUCTION

1.1 Today's pesticides

The use of pesticides for crop protection is an important part of modern day agriculture and forestry (McEwen and Stephenson, 1978). In contrast to pesticides of previous decades, today's pesticides are active at a lower application rate, less persistent, more biodegradable and more specific in their action (Kraus, 1988). Ideal selection criteria for pesticides are 1) low mammalian toxicity (except for vertebrate pest control products), 2) rapid degradation in the environment, 3) little movement of residues to off-target areas or ecosystems, 4) high specificity and toxicity towards target pests, 5) low toxicity towards non-target organisms and 6) low bioaccumulation potential (NRCC Persistence Model, 1988). Realistically, the only criteria which have been met to date are reduced persistence and lowered mammalian toxicity.

The diversity in the chemical structure of pesticides, however, has not decreased. The environmental impact evoked by these pesticides may well be as diverse as the chemical structures themselves. This environmental influence is regulated by the inherent physicochemical properties of the pesticide which, in the environment, affects the compound's polarity, solubility, volatility, reactivity, degradation, bioaccumulation, run-off and leaching potential (Seiber, 1987).

The most important classes of pesticides are herbicides, insecticides, antimicrobials, fungicides, fumigants, plant growth regulators, piscicides, molluscicides, rodenticides, avicides, lampreycides, and other vertebrate pest controls. These are used not only in agriculture and forestry, but also in man's fight against the spread of diseases such as malaria, typhoid, plague or sleeping sickness (Murty, 1986).

1.2 Pesticides in Canada

In Canada, about 500 pesticide active ingredients (AI) are registered for use in approximately 5,000 pest products (Pierce and Wong, 1988). In total, 36,175 metric tons of AI were sold in Canada in 1985 of which 80% were herbicides, insecticides and fungicides. Of this group, 83% were herbicides, 9% insecticides and 8% fungicides (Environment Canada/Agriculture Canada, 1987). The Prairie Provinces (Manitoba, Saskatchewan and Alberta) buy 69 and 51% of the herbicides and insecticides sold in Canada, respectively. In Quebec, 2,665 metric tons (13% of Canadian total) of pesticides were purchased. Of these, the important chemical groups were the triazines and triazoles, the carbamates, the amide derivatives, the aryloxyacids, the organophosphates, the phtalimides, the organochlorines, the quaternary ammonium and phenol derivatives, the substituted ureas, the organic halogen acid derivatives, and others such as the natural insecticide, Bacillus thuringiensis.

1.3 Pesticides in Quebec

Between forestry and agriculture, the latter accounts for the greatest quantity of pesticides used in Quebec (SAGE, 1988). Since the number of agricultural pesticides alone is exceedingly large, efforts have been made to select priority compounds for studies.

Forty priority pesticides (Table 1) were chosen in Quebec according to the following criteria (SAGE, 1988):

The quantity sold in Quebec (1985)
The toxicity (fish, mammal and bird)
The environmental persistence
The carcinogenicity
The urban and forest use
The density of utilization in Quebec
Other intervening preoccupations

Table 1: Priority pesticides for the Quebec Region (SAGE, 1988)

Herbicides	Insecticides	Fungicides
atrazine	aldicarb	benomyl
butylate	azinphos methyl	captafol
2,4,-D	B.T.	captan
2,4,-DB	carbaryl	mancozeb
dinoseb	carbofuran	maneb
glyphosate	chlordane	metiram
linuron	chlorpyrifos	thiram
MCPB	cyhexatin	
metolachlor	diazinon	
paraquat	disulfoton	
picloram	endosulfan	
	fenitrothion	
	fonofos	
	malathion	
	methamidophos	
	methoxychlor	
	mevinphos	
	parathion	
	permethrin	
	phorate	
	terbufos	

In Quebec, the recent focus of the pesticide program has been on the St. Lawrence River since numerous areas of agricultural activity are in its vicinity. One case study revealed that the most prominent detections were of two types: (1) triazines, such as atrazine and its metabolites, DEA and DIA, and (2) chlorophenoxyacetic acids, such as 2,4-D, 2,4,5-T and Silvex (Duval and Gauthier, 1986). The concentrations of these herbicides ranged from non-detectable (nd) to 13.33 ug L^{-1}. In general, the contamination of the St. Lawrence River waters by herbicides was below the Water Quality Guidelines (WQG) with the exception of atrazine contamination in some areas south of Lake St. Pierre where concentrations ranged from nd to 11 ug L^{-1}

(Duval and Gauthier 1986). Also in the routine surveillance network of the St. Lawrence River, detections of α-BHC and lindane were found in 95% and 65% of the samples collected (Germain and Langlois, 1989).

The basin of the Yamaska River (a tributary of the St. Lawrence) is an area of intense agricultural activity (SAGE, 1988). According to Muir et al. (1978), concentrations of atrazine and its metabolites in the water of the Yamaska River and its tributaries ranged from 0.01 to 26.9 ug L^{-1} over the monitoring period which extended from April to December in 1974 and 1975. The highest levels of atrazine were observed in July which coincided with the spraying season and heavy rainfall events. Losses of atrazine were estimated to represent 0.1 to 2.9% of the pesticide applied. Concentrations of hexachlorobenzene, dieldrin, γ-chlordane, lindane and heptachlor were found in some fish samples taken in 1977-1978 from the Yamaska River (Harvey, 1979). DDT was also found in the fish at concentrations ranging from 0.1 to 0.2 mg kg^{-1} wet weight (Laliberté and Goulet, 1983). In a study of centrifuged water samples taken from the mouth of the Yamaska River, McGuire et al. (1989) detected the presence of the following organochlorine pesticides: lindane, heptachlor, heptachlor epoxide and endrin. Oxydemeton-methyl, dichlorvos, acephate, mevinphos, trichlorfon, demeton-S, naled, sulfotepp, dimethoate, demeton-O, atrazine, terbufos, diazinon, disulfoton, promethryn, malathion, fenthion,

chlorpyrifos, parathion, cyanazine, anilazine, methidathion, crotoxphos, ethion and phosalone were also detected in these samples.

Another tributary of the St. Lawrence River, the St. Francois, has also been studied even though it harbours significantly less agricultural activity than the Yamaska (SAGE, 1988). DDT was detected in fish taken from the St. Francois River in concentrations up to 0.3 mg kg^{-1} wet weight (Laliberté and Goulet, 1983). Suckers and pike taken from the St. Francois were also found to contain similar levels of DDT (Laliberté and Goulet, 1984). McGuire et al. (1989) detected the same pesticides as were found in the Yamaska (listed above) at the mouth of the St. Francois except for the following: acephate, mevinphos, demeton-0, diazinon, disulfoton, fenthion and parathion and with the addition of dieldrin and metribuzin.

1.3 Pesticide route of entry and fate in aquatic systems

Sources of direct contamination to aquatic systems by pesticides may be due to over-spray, aerial drift, careless handling, accidental spills, improper disposal and actual treatment of basins. Pesticides applied to foliage and soil cause contamination from surface runoff and leaching to groundwater (Pierce and Wong, 1988).

Understanding the transfer of pesticides from one environmental compartment (surface water, groundwater, precipitation, soil, sediment, air, biota) to another has become very important in the interpretation of monitoring data (Rao et al., 1983; Green and Khan, 1987). Contamination of one compartment can affect the others (Organization de Cooperation et de Developpement Economique (OCDE), 1986). The transport and fate of pesticides in the environment is ruled by a complex set of parameters all of which act together (Pierce and Wong, 1988). These parameters include climatic and geographic conditions, volume and location of pesticide use, mode of application, potential for long range transport as well as the chemical nature and reactivity of the pesticide itself (Weber et al., 1981; Hurtig, 1972; O'Neill and Bailey, 1987)

Numerous interrelated factors influence how much of field-applied pesticide gets into the river via runoff and leaching. The most important of these factors are intensity and duration of rainfall (or snow-melt), the quantity and seasonal timing of pesticide application and the length of time between the application and the precipitation (Muir et al., 1978, Weber et al., 1981; Pierce and Wong, 1988). The largest losses of pesticides occur when a heavy rainfall takes place shortly after application, when runoff and erosion losses are greatest (Weber et al., 1981).

Precipitation augments pesticide contamination by increasing the volume of surface runoff and/or leaching through the soil to the groundwater (Pierce and Wong, 1988). The loss of modern pesticides through surface run-off usually represents 0.5% of the amount applied. This percentage can vary, however, according to the magnitude of precipitation, the slope of the land as well as the formulation and nature of the pesticide (Wauchope, 1978; Pierce and Wong, 1988). Losses of up to 20% have been documented for soluble pesticides following severe precipitation events. Studies have shown that of the total atrazine lost to runoff, 16 to 24 % of it was removed from the fields via tile drains, whereas, 51 to 62 % discharged through storm runoff (Frank, 1986). Leaching to groundwater is influenced by the magnitude of precipitation since this affects the volume of water available to transport pesticides to the water table (McRae, 1989). Some Ontario studies have shown that normal field application of pesticides does not contaminate groundwater through leaching although the study was limited to atrazine (Frank et al., 1987). Precipitation also effects river flow which plays a role in the transport, dilution and loading of pesticides (Muir et al., 1978).

As well as the timing of pesticide application (see Appendix 6), the actual amount applied is important in determining the extent of contamination (Muir et al., 1978). Very little data exists in this latter respect, however, in Quebec the sales

estimates for each river basin under study can be used as a guide. The most recent sales data for the basins in this report are those from 1982 (SAGE, 1988).

The environmental fate of pesticides is also mediated by the physical and chemical properties of the pesticide itself (pKa, solubility, soil adsorption, volatility, degradation) in conjunction with the type and amount of ground cover and tillage practices, the percent slope of the land and the method of pesticide application (Weber et al., 1981). Persistence is another factor to be considered, although, it can vary greatly for a given pesticide depending on environmental conditions such as microbial activity, soil type, water content, pH, temperature as well as photodecomposition, evaporation and bound residue formation (Pierce and Wong, 1988).

Sorption to soil is an important factor determining the transport and fate of pesticides in the environment. Pesticides can be grouped in specific classes: basic, acidic, arsenate, phosphate, nonionic and highly water soluble, nonionic and moderately water soluble and nonionic with a low water solubility according to their soil sorption capacity (Weber et al. 1981). The particle binding capacity of each of these classes varies according to environmental pH. Basic pesticides, such as atrazine, tend to protonate at low pH, subsequently binding to the cation exchange sites of soil colloids. At normal pH (5 to 9)

basic pesticides become more mobile while acidic pesticides (eg 2,4-D and MCPA) form anionic species which also do not bind to soil colloids since they are negatively charged. Arsenate and phosphate pesticides easily bind to the clay minerals in soils and as a result are not very mobile, moving only with eroding particles. Nonionic pesticides are not affected by pH, rather their mobility is determined by chemical structure, water solubility and vapour pressure (Weber et al., 1981). Other indicators of the soil-binding potential of pesticides are the octanol-water partition coefficient (Kow) and the soil organic carbon partition coefficient (Koc) which describe the affinity of a chemical for soil particles. Kow values are indicators of soil sorption and bioconcentration in the fatty tissues of organisms. Representative of the potential binding to organic matter in the soil particle, Koc values greater than 1000 define tight binding to the soil, whereas, values below 100 indicate high water mobility (Kenaga and Goring, 1980). Koc values are good indicators of soil binding only for nonionic pesticides, with more polar compounds, ionization and the mineral content of soils becomes important. In general, non-ionic chemicals with a low solubility and high Koc and Kow tend to be less mobile. Kow and Koc values must, however, be regarded as rough estimates since contradictory values have been documented (Pierce and Wong, 1988; Environment Canada, 1989).

The vapour pressure of a given pesticide indicates how much will be dissipated by evaporation. Pesticides with low volatility (less than 10 mPa) tend to move through soil mainly via mass transport, whereas, pesticides with higher volatilities can diffuse through the soil and escape to the atmosphere. The amount of soil moisture and the degree of pesticide binding can also effect the volatility. For example, 2,4-D and MCPA losses due to evaporation can be up to 40% immediately after application on dry soil. If the soil moisture is high, however, the compounds can be hydrolysed into a non-volatile acid (Smith, 1982; Grover et al., 1985; Gile, 1983).

Groundwater contamination is often poorly understood. Since groundwater moves very slowly, it may not return to the surface waters for many years. According to Villeneuve (1985), many of Quebec's aquifers are most likely contaminated with pesticides.

The source of groundwater contamination is often difficult to determine. Spills and back siphoning can be point sources of groundwater pollution while non-point contamination is often due to runoff or leaching of pesticides applied to crops and livestock. Groundwater contamination due to aldicarb and picloram has been documented in Quebec (Pupp, 1985; Varfalvy and Séguin, 1987) In Ontario, 259/359 wells were found to be contaminated with atrazine and 2,4-D (Frank et al., 1987).

The leaching potential of a given pesticide is determined by a number of factors, many of which are interrelated. The texture of surface soils plays a major role: leaching is faster and deeper in course or lightly textured soils (eg. sand and sandy loams), whereas, in fine textured soils (eg. clay) water passes through at a much slower rate due to the harbouring of silt and organic matter to which pesticides can adhere or adsorb. The parent material beneath the surface soil also affects leaching. Due to the highly permeable nature of sands and gravels of fluvial and glacial origin, these parent materials are very vulnerable to leaching. The clays of marine and lacustrine origin offer the best protection to underlying waters. The routes and degree of groundwater contamination are also limited by various soil and non-soil factors which are reviewed by McRae (1989).

Pesticides are often applied to agricultural systems concurrent with fertilizers both of which are considered to be sources of non-point contamination. Of the major constituents of fertilizers, phosphorus, nitrate and potassium, the former two are defined as major causes of non-point agriculture-related contamination (Mostaghimi et al., 1987). Fertilizer pollution has direct negative impacts on the environment (eg. eutrophication) specifically on the growth of algae which are organisms that may provide a metabolic sink for pesticides (Lakshminayana and Bourque, 1980; Zepp, 1980).

1.4 Water Quality Branch (Quebec) pesticide program (now a part of the Hydrology and Networks section of the Centre Saint-Laurent)

The purpose of a water quality surveillance and monitoring program is to study how the presence, levels and environmental impact of contaminants affect the use of that water resource. Furthermore, the determination of exposure to a specific chemical is one measurement which reflects a possible perturbation to the environment and ultimately its effect on man (Müller, 1988). In the Water Quality Branch (WQB) of Environment Canada in the Quebec region, such a program did not come into effect for in use or currently registered pesticides until 1987.

This report outlines the monitoring and surveillance efforts carried out by Environment Canada's WQB at the Longueuil research station in 1987 and 1988. Sampling sites in areas of intense agricultural activity in Quebec were chosen for the investigative pesticide program. The majority of these rivers are tributaries of the St. Lawrence River. The data and interpretations for the two year pesticide program are given in this report. The study included monitoring of surface water, suspended sediments, bottom sediments and fish. It is emphasized that this was a preliminary study designed to reveal presence and trends, therefore, at this time, cannot be supported by any extensive statistical validation. The objectives that were set are stated below.

1.5 Objectives

1) To acquire information regarding the presence, levels and localization of pesticide contamination in tributaries of the St. Lawrence River.

2) To gather the necessary information required for the re-evaluation of currently registered pesticides. Since some of the data presented in this report deals with CEPA priority contaminants, the findings could aid the CEPA personnel in their ongoing re-evaluation of this list. Similarly, the pesticide data could become part of the information base used by Agriculture Canada in the registration and deregistration of new and existing pesticides.

3) To study the chemical fate of pesticides in waters proximal to intensive agricultural zones of Quebec.

4) To implement a monitoring program to assess the current and future levels of pesticide contamination of water resources.

2.0 MATERIALS AND METHODS

2.1 Stations

The sampling sites used for the 1987-1988 pesticide program are listed in Table 2. In 1987, the Yamaska and the St. Francois Rivers were sampled, while in 1988 the following rivers were also included: the Assomption, the St. Jacques, the St. Regis and the Tortue. Of the six river basins, four, the Yamaska, the St. Jacques, the St. Regis and the Tortue are in areas of intense agricultural activity, while in the remaining two basins, agriculture is of substantially lesser importance.

Table 2: Sampling Program for 1987-1988

River	Site*	Material	Year(s)
Yamaska	mouth	water	1987-1988
		SPM	1987
		bottom sediment	1987
		fish	1987
Yamaska South	mouth	water	1988
Yamaska Tributaries			
Chibouet	mouth	water	1988
David	mouth	water	1988
St. Francois	mouth	water	1987-1988
		SPM	1987
		bottom sediment	1987
		fish	1987

(Table 2 continued)

St. Francois Tributaries			
St. Germain	mouth	water	1988
Aux Vaches	mouth	water	1988
Assomption	mouth	water	1988
		bottom sediment	1988
Assomption Tributaries			
Achigan	mouth	water	1988
Ouarou	mouth	water	1988
St. Regis	mouth, A1, A2**	water	1988
		SPM	1988
		bottom sediment	1988
St. Jacques	mouth, A1, A2**	water	1988
		SPM	1988
		bottom sediment	1988
Tortue	mouth, A1, A2**	water	1988
		SPM	1988
		bottom sediment	1988

* Samples of water, SPM and bottom sediment may not have been taken from identical locations on a given river since sediment was not always available at the water sampling sites. Exact locations of all sampling sites are listed in Appendix 4.

**A1 and A2 refer to sites upstream from the river's mouth (see Appendix 4).

2.2 Sampling Protocol and Methods of Preservation

2.2.1 Water

Near the mouth of the Yamaska, St. Francois and Assomption Rivers, a composite sample was taken from three locations equally spaced across the width of the river. At each of the sites on the St. Regis, St. Jacques and Tortue Rivers and the tributaries of the Yamaska and the St. Francois the samples were taken at a single central location (Table 2, Appendix 9).

At each collection location pH, conductivity, temperature and dissolved oxygen were measured in situ. A 4.5 L water sample was collected from a depth of 1 m and decanted into a 20 L clean glass container which had been previously rinsed several times with river water. In between sampling points, the 20 L container was covered with aluminum foil to avoid contamination. The above procedures were done either from a boat or a bridge.

After collecting the water samples from all three sites, the contents of the 20 L container was thoroughly mixed and distributed among several different smaller containers each designated for a certain type of analysis and containing the relative preservative if applicable (Table 3). Containers not requiring preservative were filled first followed by those containing sulfuric and nitric acids. These containers were then

placed in a cooler containing ice. Upon return to the laboratory, the samples were preserved as shown in Table 3.

Since the Yamaska River was sampled in May and June in 1988 and in June to October in 1987 both sets of data were displayed on the same graph (Figures 3a to h). Graphs of pesticide contamination were only made if the levels of the given pesticide exceeded the WQG in two or more samples.

Table 3: Methods of preservation for water samples designated for specific analysis

Type of Analysis	Method of Preservation*
Triazines	4°C
Amide derivatives	4°C
Organochlorines	4°C
Phenoxyacids	5.0 ml 30% H_2SO_4, 4°C
Carbamates	0.4 ml 30% H_2SO_4, 4°C
Organophosphates	0.2 ml 30% H_2SO_4, 4°C (3<pH<4)

*all containers were made of glass and had a volume of 1.12 L

2.2.2 Precipitation and River Flow Rate

The precipitation and flow data was communicated by Aubin and Miron (personal communications, 1989) from Environment Quebec.

2.2.3 Suspended Particulate Matter (SPM)

SPM samples were taken from the Yamaska and St. Francois Rivers in 1987 and from the St. Regis, St. Jacques and Tortue Rivers in 1988 (Table 2, Appendix 9).

A 500 L sample of water was pumped from each of three locations at equal intervals across the width of the river. This water was put into two 550 L containers stationed on the boat. A total of 1,500 L of water was brought to shore, pumped into a Westfalia centrifuge (retention capacity of 85-90%) at a rate of 4 L min^{-1} and centrifuged at 10,000 rpm. Some of the clarified water (approx. 5 L) was passed through an XAD-2 resin tube column for organics at a flow rate of 150 ml min^{-1}. Further, a 5 L sample was reserved for other analyses, namely, dissolved major ions and trace metals. The above protocol was used for the Yamaska and St. Francois Rivers. For the smaller rivers, the 1,500 L sample was pumped from one location in the middle of the river to a reservoir and then to the centrifuge, whereafter the above protocol was used.

Immediately following centrifugation, the samples of SPM were scraped from the sides of the bowl with a teflon policeman, transferred to an aluminum container specially prepared for organic analyses and put into coolers containing ice. At the end of the day, they were taken back to the laboratory and frozen at -20°C.

2.2.4 Clarified water

The pesticides were concentrated in the field with a XAD-2 resin column since these contaminants are often present in very low concentrations in water.

At the sampling site, the clarified water was pumped into the XAD-2 resin column through the use of a Seastar Water Sampler (Germain et Langlois, 1989). These extraction columns were then sent to a private laboratory for analysis. These laboratories have collaborated with Environment Canada in the development of techniques for the preparation and analyses of the above-mentioned samples (Couture et Caron, 1986; Roche Environnement, 1985).

2.2.5 Bottom sediments

The bottom sediment was collected using an Ekman (regular and extra tall) dredge from the rivers listed in Table 2 and shown in

Appendix 9. From each batch of sediment, only the top 5 cm were retained. Two L of sediment were collected, homogenized and aliquoted into several different aluminum and plastic containers. These containers were then stored on ice in a cooler and later frozen at -20°C.

2.2.6 Fish

Samples of the following types of fish were taken from the Yamaska and St. Francois Rivers in 1987: Spottail Shiner (Notropis hudsonius), Emerald Shiner (Notropis atherinoides) and Yellow Perch (Perca flavescens). Young of the year fish were chosen because of their potential as bioindicators of local, recent contamination.

A 30.5 X 2.4 m net with a mesh size of 0.64 cm was used to collect the fish. A weight was attached to the bottom of the net in order to crush interfering vegetation and to prevent fish from escaping. Collection of the fish samples was usually done from a 7 m motorized boat, although, in waters with a depth of less than 0.5 m, it was done by wading.

After each net was drawn in, the fish were put in a rectangular box and identified according to species. Unwanted fish were put back in the river.

The fish of interest were then quickly wrapped in hexane-washed foil, put into a plastic bag and stored on dry ice in a cooler. Upon return to the laboratory, the fish were stored at minus 20°C (Guay, 1987).

2.3 Physical and chemical analyses

2.3.1 Raw and clarified water

The majority of the physical and chemical analyses were done according to the methods described in Environnement Canada (1983). The pesticide analyses were done either at the National Water Quality Laboratory (Burlington, Ontario) or at the regional laboratory (Longueuil, Quebec) and NOVALAB Limited (Montreal, Quebec). Any analyses done at the Burlington and Longueuil laboratories were performed according to Environment Canada's (1983) methods, while those carried out at NOVALAB utilized protocols modified from Environment Canada (1983) and from Environment Quebec (1980) (Crowley, personal communication, 1989).

2.3.2 Suspended and bottom sediments

Pesticides and PCB analyses were done at Novalab Limited according to protocols modified from Environment Canada (1983) and from Environment Quebec (1980) (Crowley, 1989).

2.3.3 Fish

In preparation for analysis, 50 to 60 frozen fish of each species (per sampling date) were ground up and homogenized. One replicate of each mixture was sent for analysis.

All fish samples were analyzed for pesticides listed in Appendix 1. The analyses were done at Novalab Limited modified from Environment Canada (1983) and Environment Quebec (1980) (Crowley, 1989).

2.3.4 Microtox toxicity assays

The stations from which water was sampled are listed in Appendix 8. One g of NaCl was added to 50 ml of surface water and mixed thoroughly. The pH was adjusted to 7 and the sample stored at 4°C until analysis.

A Microtox Toxicity Analyzer (model 2055, Microbics) and a Beckman Recorder were used to analyze the samples. All samples were initially screened at 100% strength and only those inducing at least 40% inhibition were further diluted and analyzed. Within a volume of 1 to 2 ml, dilutions of 12.5, 25, 50, 66.6 and 75% were made. These and the stock solution were allowed to stabilize at 4°C within the Microtox apparatus. Each of these samples were then inoculated with 10 ul of luminescent bacteria. An initial

reading was taken followed by two more readings at 5 and 15 min (Beckman Microtox System Operating Manual, 1982, Bureau de normalization du Québec, 1987).

2.4 Computer and Statistical Analyses

All graphs and correlations were done on a Microvax II computer (system # BT00109) with RS1 Release 3.0 software. Statistics (using Spearman Rho (SR) correlations) were done on selected sets of samples to ensure the quality of the data. For spacial quality control, correlations were carried out between samples collected from different sites across the width of a river. Three replicate samples from a given site were analyzed to ensure inter-sample quality control. A quality control comparison was also done between regular samples and samples which consisted of a mixture of samples collected each hour over a 24 hour period ("manual" samples).

3.0 RESULTS

3.1 Water

3.1.1 Yamaska River

3.1.1.1 Variation of atrazine concentration in time

In the 1988 sampling season (May 11 to June 28) the atrazine concentration in the Yamaska River water ranged from nd to 2.1 ug L^{-1}, the maximum being recorded on June 21 (Figure 3a, Table 6). The atrazine concentration remained generally below the WQG of 2 ug L^{-1} (for freshwater aquatic life) during the 1988 sampling season, in this case only 1/6 water samples were above the guideline (Table 4).

In the 1987 season (June 30 to October 14), the concentrations of atrazine ranged from 2.1 to 17.5 ug L^{-1}, the maximum being recorded on the July 7 sampling date (Figure 3a, Table 6). The remainder of the sampling season was characterized by decreasing concentrations of atrazine, although all detections (8/8 samples) were above the guideline (Table 4).

3.1.1.2 Other detections of pesticides

Also detected in the Yamaska River water (and its tributaries) in the 1988 sampling season were metolachlor and diazinon (Table

6). In 1987, 2,4-D, picloram, metolachlor, α-BHC and cis-chlordane were detected (Table 6).

3.1.1.3 Comparisons and correlations of atrazine concentration with precipitation, river flow and levels of SPM, nitrites-nitrates and phosphorus.

Figures 3b and 3c illustrate the relative levels of atrazine, precipitation, river flow rate, SPM and nitrites-nitrates in the 1987-1988 sampling season for the Yamaska River. All the data has been converted to % maximum, the maximum value used being the same in both years. Figures 3d to 3h are detailed correlation comparisons of atrazine concentration with the variables mentioned above.

In the 1987 sampling season, shown in Figure 3b, the nitrites-nitrates' profile was similar to that of atrazine; a peak in early July and tapering off for the remainder of the sampling period. The concentration of SPM was high (70% maximum) on the first sampling date and decreased by 40% by mid-July. This decrease preceded the atrazine and nitrites-nitrates decreases by about one week. In contrast to the atrazine/nitrites-nitrates profile, the relative concentrations of SPM increased slightly by the July 21 sampling date, dipping for the next two weeks, and then increasing by Aug 6. The first precipitation peak occurred four days prior to the atrazine and nitrites-nitrates maxima. Throughout the remainder of

the sampling period, there were several smaller precipitation peaks, two of which (July 20 and August 2) were followed by small SPM peaks. The relative river flow was high on June 30 then decreased rapidly until the 4th of July. On the 5th of July, there was a small increase in flow two days after a peak in precipitation. This pattern of precipitation peaks followed by flow peaks repeated itself for the rest of the sampling season.

In Figure 3c, (1988 season) the relative concentration of SPM was fairly constant (30% maximum) until the June 7 sampling date after which it increased for the remainder of the season. In contrast, the nitrites-nitrates' concentration decreased until June 7 then leveled off for the final sampling dates. The precipitation peaks were followed about two days later by river flow rate peaks, a relationship similar to that obtained in the 1987 season.

The correlations listed in Figure 3d and 3e were carried out using the raw data for atrazine correlated with the average sum of precipitation or river flow in the interval preceding the pesticide sampling date. As shown in Figure 3d, the correlation between the pesticide and precipitation data in the 1988 sampling season was very low ($r=-0.14$). There was no correlation between the precipitation and atrazine peaks. Although the correlation value is somewhat higher in the 1987 season, a consistent pattern between these sets of peaks was not evident. One exception to this was the precipitation peak on July 3rd (maximum for the Yamaska River)

which was followed, a few days later, by the maximum peak of atrazine concentration.

The variation of atrazine concentration and river flow are shown in Figure 3e. In the 1988 sampling period, the river flow rate increased until May 16, then decreased until June 21 and finally increased again in the last week of the sampling season. This pattern of river flow data proved to have a negative correlation with the atrazine data ($r=-0.70$). Conversely in the 1987 sampling season, the correlation was positive ($r=0.77$). Both atrazine concentration and river flow decreased over the course of the summer, the only difference being that atrazine increased from the first to the second sampling day.

There was a positive correlation ($r=0.58$) between the concentrations of atrazine and SPM in the Yamaska River for the 1988 sampling season (Figure 3f). The first small SPM peak occurred one week prior to a small atrazine peak. Between the 7^{th} and 21^{st} of June, both the atrazine and the SPM values increased. The SPM value increased further by the last sampling date, in contrast to the atrazine level which dropped slightly.

In the 1987 sampling season, the correlation between atrazine and SPM was slightly negative ($r=-0.14$) (Figure 3f). On the first sampling date the concentration of atrazine was low (3.6 ug L^{-1}), while that of SPM was relatively high (15.6 ug L^{-1}). Over the

course of the following two weeks, the atrazine concentration increased then decreased, the latter being concurrent with a steady decrease of SPM. Between the July 14 and 21 sampling dates, the SPM increased while the atrazine concentration remained constant. Both atrazine and SPM had similar profiles of slight decrease followed by an increase for the last three sampling dates.

As shown in Figure 3g, the nitrites-nitrates' concentration (1988 sampling season) decreased until June 7 concurrent with low unvarying atrazine concentrations. After June 7, the nitrites-nitrates' concentration increased slightly as did that of atrazine, although, the correlation between the two was extremely low (r= -0.09).

In the 1987 season (Figure 3g), there was a stronger positive correlation between the atrazine and the nitrites-nitrates' data (r= 0.83). Both of these variables increased from June 30 to July 7 then decreased for the rest of the sampling period.

As shown in the 1988 section of Figure 3h, the phosphorus concentration increased for the duration of the season, concurrent with both increases and decreases in atrazine concentration. The calculated correlation between these two sets of data was r=0.54. In contrast, the 1987 data was negatively correlated (r=-0.9), the increases in atrazine concentration corresponding with decreases in phosphorus concentration and vice versa (Figure 3h).

3.1.2 Assomption River

3.1.2.1 Variation of lindane concentration in time

At the Assomption River mouth (sampled from May 10 to June 22), the concentrations of lindane ranged from 0.00155 to 0.09580 ug L^{-1} (Figure 4a, Table 6). Until the May 24 sampling date, the concentrations remained low and then peaked a few weeks later to a maximum concentration one order of magnitude above the guideline level. For the remainder of the season, the lindane levels gradually decreased, 4/5 of the samples collected having lindane levels above the WQG (Table 4).

3.1.2.2 Other detections of pesticides

Also detected in the Assomption River were the following pesticides: α-BHC, dieldrine and p,p'-DDE (Table 6).

3.1.2.3 Comparisons and correlations of lindane concentrations with precipitation, river flow and the levels of SPM, nitrites-nitrates and phosphorus

In Figure 4b, the lindane profile does not correspond with the variation of the other parameters of the water of the Assomption River. After maintaining a relatively low concentration from May 10 to 25, the lindane level increased to a maximum on the June 8

sampling date. In the same interval, the SPM, the nitrites-nitrates, the profile of precipitation peaks and the river flow all decreased. After the June 8 sampling date, the relative concentration of lindane decreased, similar to that of nitrites-nitrates, precipitation peaks and river flow. The SPM remained stable until June 15 when it began to increase.

A negative correlation between the lindane concentration and the profile of precipitation peaks is clearly evident (see Figure 4c). The three precipitation peaks decreased between May 10 to 25, whereas, the concentration of lindane remained low.

As shown in Figure 4d, there was a negative correlation between the lindane concentration and the river flow ($r=-0.50$). Over the course of this sampling season, the rate of river flow steadily decreased while the lindane concentration both increased and decreased.

A negative correlation ($r=-0.67$) was found between the relative concentrations of lindane and SPM in the Assomption River (Figure 4e). Between the 10^{th} and 25^{th} of May, both variables decreased and then correlated negatively for the remainder of the season. The lindane levels increased until June 8, then decreased while the SPM decreased and increased over the same time interval.

As shown in Figure 4f, there was a negative correlation (r=-

0.31) between the lindane and nitrites-nitrates' levels in the Assomption River. Both lindane and nitrites-nitrates' concentrations decreased between the first two sampling dates. From May 25 to June 8, the nitrites-nitrates' concentration leveled off while lindane increased to a maximum value (0.10 ug L^{-1}) ten times that of the guideline. For the final sampling dates both variables gradually decreased.

In Figure 4g, there was a slight correlation between the concentrations of lindane and phosphorus in the Assomption River (r=0.10). From May 10 to 25, the concentrations of both variables decreased. By June 8, the lindane level had increased to its maximum and this was concurrent with a slight increase in the concentration of phosphorus. Between June 14 and 22, there was a negative correlation between the two data sets (Figure 6f).

3.1.3 St. Regis River

3.1.3.1 Variation of atrazine and diazinon concentrations in time

The St. Regis River was sampled from June 23rd to Aug 15th in 1988 at the mouth and two upstream sites (A1 and A2). The concentration of atrazine ranged from 1.3 to 21.5 ug L^{-1}, the maximum being collected on June 23 at site A2 (Figure 5a, Table 6). The WQG was surpassed in 5/9 samples taken from this river (Table 4).

As shown in Figure 5a, the concentration of atrazine remained below WQG for the first two sampling dates, to exceed it only on the August date. This pattern of slight increase contrasted with that found at the A1 and A2 upstream sites. Atrazine concentrations at both of these sites surpassed the guideline by more than one order of magnitude on the first sampling date. At site A1, the atrazine concentration dropped to slightly above the guideline level for the final two sampling days, while at the A2 site the levels were below the guideline on both these final dates.

In the St. Regis River, the concentrations of diazinon ranged from 0.13 to 28.3 ug L^{-1}, the maximum being found on June 23 at site A2 (Figure 5b). The WQG for diazinon was surpassed in 9/9 samples taken from this river (Table 4). A pattern similar to that seen in Figure 5a is apparent in Figure 5b, although, in the latter all concentrations of diazinon were above the guideline. Again, the pesticide concentrations rose moderately over the three sampling dates at the river's mouth, the final value being about 75 times the guideline level. Upstream, diazinon concentrations at sites A1 and A2, were both at least 300 times greater than the guideline levels on the June sampling date. This was followed by decreases for the remainder of the sampling season.

3.1.3.2 Other detections of pesticides

Also found in the St. Regis River were the following pesticides: butylate, alachlor, 2,4-D. α-BHC, lindane, p,p'-DDE, α-endosulfan and cis-and trans-chlordane (Table 6). Pesticides from this list which exceed the guideline are listed in Table 4.

3.1.3.3 Correlations of the concentrations of atrazine and diazinon with precipitation and the levels of SPM and nitrite-nitrates

Figures 5c to 5e are % maximum comparisons of atrazine, diazinon, SPM, nitrites-nitrates and precipitation in the St. Regis River. The river flow data was not available. The same maximum values were used for all three sampling sites along the length of the river.

At the mouth of the St. Regis River (Figure 5c), the relative concentrations of the pesticides, SPM and nitrites-nitrates stayed relatively low and constant from the first to the second sampling date. The profile of precipitation peaks decreased over this time interval. Between the July and August sampling dates, there was a increase in all variables including the precipitation peaks.

At the A1 station of the St. Regis River (Figure 5d), the atrazine, the diazinon and the SPM levels as well as the

precipitation peaks decreased between the first two sampling dates. During this interval, the nitrites-nitrates' concentration increased moderately. The concentrations of atrazine and diazinon remained relatively stable between the July 13 and Aug 15 sampling dates and this was concurrent with an increase in the SPM value and a decrease in the relative concentration of nitrites-nitrates. The precipitation peaks also steadily increased in this time interval.

As shown in Figure 5e, all but one of the variables decreased between the first two sampling dates at the A2 site of the St. Regis River. The exception was nitrites-nitrates which increased. Between the July 13 and August 15 sampling dates, concentrations of atrazine, diazinon and SPM stayed constant in contrast to a decrease in nitrites-nitrates levels and a steady increase in the precipitation peaks.

In comparing the pesticide and parameter profiles of the different sampling sites of the St. Regis River, some patterns emerged. At the river mouth, there was only a slight overall increase in the relative concentrations of atrazine and diazinon along with a slightly stronger increase in the level of SPM. In contrast, at sites A1 and A2, by the second sampling date the relative concentrations of atrazine and diazinon greatly decreased from an initial high to a substantially lower level and was maintained until the end of the season. On the June sampling date, the SPM concentration (48 mg L^{-1}) at site A1 was about twice that

found at the river's mouth on the same day. At sites A1 and A2, the SPM concentration decreased by the second sampling date and then increased again by the last date, the initial increase being greater at the A2 site. The nitrites-nitrates' concentration increased slightly over the course of the sampling season at the river's mouth. At sites A1 and A2, there was an increase and decrease over the course of the season which was more profound at the A2 site.

3.1.4 Tortue River

3.1.4.1 Variation of atrazine and diazinon concentrations in time

In the Tortue River, sampled from June 23 to Aug 15, 1988, the concentrations of atrazine ranged from 0.2 to 16.1 ug L^{-1}, the maximum being found at site A2 on June 23 (Figure 6a, Table 6). The WQG for diazinon was surpassed in 6/8 samples taken from this river (Table 4).

The levels of atrazine at the mouth of the Tortue River rose from a concentration well below the guideline level on the first sampling date, to slightly above this level in July (Figure 6a) By the last sampling date, it doubled in comparison to the guideline levels. At site A1, the atrazine level rose steadily over the course of the sampling season to a final value about 2.5 times that of the guideline. In contrast at site A2, there was a large

decrease in the atrazine concentration from the first to the second sampling date. Samples from site A2 were not taken in August.

The concentrations of diazinon found in the Tortue River ranged from 0.05 to 22.3 ug L^{-1}, the maximum being found at site A2 on June 23 (Figure 6b, Table 6). Seven of the eight samples taken contained detections were above the WQG (0.08 ug L^{-1}) (Table 4).

The diazinon profile (concentration vs time) was similar to the atrazine profile for the same river. At the river's mouth, a moderate increase was apparent over the course of the sampling season ending with a concentration about 65 times greater than the guideline. The concentration of diazinon found at the A1 site in June was about 36 times greater than the guideline. By July, the concentration of diazinon decreased by half, and by August it rose to a value 84 times the guideline concentration. At site A2, a 10-fold decrease from a maximum value of over 22 ug L^{-1} occurred from the June to the July sampling date. No samples were taken in August.

3.1.4.2 Other detections of pesticides

In the Tortue River the following pesticides were also found: butylate, 2,4-D, metolachlor, α-BHC, lindane, p,p'-DDE and DDT and α- and β-endosulfan (Table 6). Of these, pesticides that exceeded the WQG are listed in Table 4.

3.1.4.3 Correlations of atrazine and diazinon concentrations with precipitation and the levels of SPM and nitrites-nitrates

Figures 6c and 6d show the relative levels of atrazine, diazinon, SPM, nitrites-nitrates and precipitation at the three sampling sites of the Tortue River.

At the river's mouth (Figure 6c), the relative levels of both atrazine and diazinon increased slightly over the course of the sampling season. The SPM concentration was relatively high on the first sampling date (more than 65% of the maximum) then decreased to 15% of the maximum for the remainder of the sampling season. The concentration of nitrites-nitrates was very low on the first sampling date, increased to maximum level by the second date and decreased again by the third date. Between the first two sampling dates, there were two precipitation peaks, the first being very close to the maximum. The precipitation levels thereafter remained low for most of the sampling season, becoming elevated again only by early and mid August.

At site A1 of the Tortue River (shown in Figure 6d), the relative concentration of atrazine was low for the first two sampling dates and increased slightly by the third. The variation in the diazinon concentration was roughly similar except for a slight decrease on the second sampling date. Similarly, the SPM concentration was high on the first sampling date then increased by

the July date and decreased in August. The relative nitrites-nitrates concentration was low on the first sampling date and increased by the second, similar to what happened at the river's mouth. By the third sampling date, however, the nitrites-nitrates' concentration remained high at site A1, in contrast to the decrease at the river's mouth. The pattern of precipitation peaks follow a profile similar to the variation in SPM concentration.

At site A2 of the Tortue River (Table 6) all variables decreased from the first to the second sampling dates. A complete data set was not available for the August date.

3.1.5 St. Francois and St. Jacques Rivers

Although most of the detections were found in the other rivers listed in this section, some pesticides were found in the St. Francois and St. Jacques Rivers (those above the WQG are listed in Table 4). In the St. Francois River, sampled in 1987 and 1988, 2,4-DP and atrazine were detected. In the St. Jacques River, sampled in 1988 only, butylate, 2,4-D, atrazine, diazinon, α-BHC, lindane, p,p'-DDE and cis-chlordane were found (Table 6).

3.1.6 Pesticide concentrations exceeding the WQG for freshwater aquatic life

Table 4 includes all pesticide concentrations found to exceed the guidelines for the protection of the aquatic life in the water of the sites sampled. A complete list of all the pesticides tested for in water in this investigation is shown in Appendix 1 while the stations and dates of sampling are shown in Appendix 4.

Table 4: Pesticide concentrations exceeding the WQG for freshwater aquatic life protection

River	Pesticide	WQG ($ug\ L^{-1}$)	Date	Concentration ($ug\ L^{-1}$)	Fraction of total samples exceeding WQG
Yamaska	Atrazine	2.0	30 Jun 87	3.6	8/13
			7 Jul 87	17.5	
			14 Jul 87	6.4	
			21 Jul 87	6.2	
			28 Jul 87	3.5	
			4 Aug 87	2.1	
			6 Aug 87	2.9	
			21 Jun 88	2.1	
	Diazinon	0.08	28 Jun 88	2.2	1/13
Yamaska South	Atrazine	2.0	28 Jun 88	2.9	1/2
	Diazinon	0.08	17 May 88	0.2	2/2
			28 Jun 88	5.7	

(Table 4 continued)

Yamaska Tributaries:					
Chibouet	Diazinon	0.08	17 May 88	0.2	2/2
			28 Jun 88	2.4	
David	Diazinon	0.08	17 May 88	0.2	2/2
			28 Jun 88	3.3	
St. Francois	2,4-DP	4.0	14 Jul 88	4.6	1/12
Assomption	Lindane	0.01	10 May 88	0.0100	4/5
			8 Jun 88	0.0958	
			14 Jun 88	0.0721	
			22 Jun 88	0.0230	
Saint Regis					
A1	Atrazine	2.0	23 Jun 88	20.7	5/9
			13 Jul 88	3.7	
			15 Aug 88	2.6	
A2			23 Jun 88	21.5	
Mouth			15 Aug 88	3.5	
A1	Diazinon	0.08	23 Jun 88	25.0	8/9
			13 Jul 88	4.8	
			15 Aug 88	5.2	
A2			23 Jun 88	28.3	
			13 Jul 88	1.9	
			15 Aug 88	3.0	
Mouth			13 Jul 88	2.0	
			15 Aug 88	6.0	
A1	Lindane	0.01	23 Jun 88	0.0185	2/9
			15 Aug 88	0.0132	

(Table 4 continued)

St. Jacques Mouth	Atrazine	2.0	14 Jul 88	11.3	1/3
	Diazinon	0.08	14 Jul 88	19.7	1/3
Tortue A1	Atrazine	2.0	23 Jun 88	2.3	6/8
			12 Jul 88	2.7	
			15 Aug 88	5.0	
A2			23 Jun 88	16.1	
Mouth			12 Jul 88	2.8	
			15 Aug 88	4.4	
A1	Diazinon	0.08	23 Jun 88	2.9	7/8
			12 Jul 88	1.4	
			15 Aug 88	6.7	
A2			23 Jun 88	22.3	
			12 Jul 88	2.0	
Mouth			12 Jul 88	3.8	
			15 Aug 88	5.2	
A1	Lindane	0.01	12 Jul 88	0.07720	1/7
A1	p,p'-DDE	0.001	23 Jun 88	0.0141	3/7
			15 Aug 88	0.00154	
A2			23 Jun 88	0.00286	
A2	α-endosulfan	0.02	23 Jun 88	0.0696	2/7
			15 Aug 88	0.02040	
A1	p,p'-DDT	0.001	23 Jun 88	0.0162	3/7
			15 Aug 88	0.0017	
A2			23 Jun 88	0.00513	

(Table 4 continued)

A1	β-endosulfan	0.02	15 Aug 88	0.035	2/7
A2			23 Jun 88	0.04	

Out of a total of 13 sampling dates for the Yamaska River in 1987-1988, eight samples were found to contain concentrations of atrazine exceeding the guideline levels, while only one out of the 13 samples contained a level of diazinon higher than the guideline.

In the Southern portion of the Yamaska River, the atrazine concentration exceeded the guideline on one of the two sampling dates. The guideline for diazinon was exceeded on both sampling dates of the tributaries, the Chibouet and the David and the mouth of the Yamaska South River.

In the water samples taken from the St. Francois River, the guideline level for 2,4-DP (4 ug L^{-1}) was exceeded in only one of the 12 sampling dates.

Most samples taken from the Assomption River (excluding the Achigan tributary), contained concentrations of lindane which exceeded the guideline of 0.01 ug L^{-1}.

In the St. Regis River, concentrations of atrazine, diazinon and lindane exceeding the guidelines were found at all three sites along the length of the river. Atrazine levels surpassed the

guideline in 5/9 sites, diazinon in 8/9 sites and lindane in 2/6 sites.

The concentrations of atrazine and diazinon were found to exceed their respective guidelines at the mouth of the St. Jacques River on the July 14 sampling date.

Atrazine, diazinon, lindane, α- and β-endosulfan, p,p'-DDT and p,p'-DDE concentrations all surpassed their respective guidelines in the Tortue River. Atrazine, diazinon and lindane exceeded the guidelines in 6/8, 7/8, and 1/7 stations, respectively. The p,p'-DDT and its degradation product, p,p'-DDE were present in 3/7 stations while α-endosulfan appeared 1/7 times and β-endosulfan 2/7 times.

3.1.7 Loading of pesticides into the St. Lawrence River

As shown in Table 5, on the 7^{th} of July 1987, the maximum measure of atrazine concentration was found in the Yamaska River. From this concentration and the river flow data, a loading rate of 0.29 g s^{-1} (25 kg per day) was calculated for atrazine entering the St. Lawrence River. Similarly, on June 8, 1988 (the sampling date on which the maximum concentration of lindane was found) 0.029 g s^{-1} or 2.5 kg per day of lindane was calculated as being loaded into the St. Lawrence River.

Table 5: Maximum loading of pesticides into the St. Lawrence River from the Yamaska and Assomption Rivers.

Site	Pesticide	Date	Calculated Flow* (mc/s)	Concentration of Pesticide (ug L^{-1})	Calculated Loading ($g\ s^{-1}$)
Yamaska (mouth)	atrazine	7 Jul 87	16.8	17.5	0.29
Assomption (mouth)	lindane	8 Jun 88	30.6	0.9580	0.029

*calculated from the river flow from the hydrological stations 030341 (Yamaska) and 052219 (Assomption). In order to estimate the flow at the rivers mouth, a correction factor was provided by Environment Quebec.

The rate of pesticide loading and the corresponding pesticide concentrations into the St. Lawrence River on each sampling date of the Yamaska and Assomption Rivers are shown in Figures 1 and 2.

3.2 Pesticides in SPM and bottom sediments

As shown in Table 7, atrazine was found in the SPM and bottom sediments of the Yamaska River. In the St. Jacques River, α-BHC and cis-chlordane were found in both the SPM and bottom sediments, while trans-chlordane, p,p-DDT and p,p-DDD were found only in the SPM and 2,4,5-T only in the bottom sediments. In the SPM of the St. Regis River, β-BHC, cis-chlordane and p,p-DDT were detected, while hexachlorobenzene, 2,4-DP, 2,4-D and 2,4,5-T were found only in the

bottom sediments. In the Tortue River, α-BHC, cis-and trans-chlordane, p,p-DDT and p,p-DDE were found in both the SPM and bottom sediments. Concentrations of 2,4,5-T were found only in the SPM, whereas, 2,4-D was found only in the bottom sediments. In the Assomption River bottom sediments both MCPA and 2,4-D were detected.

3.3 Fish

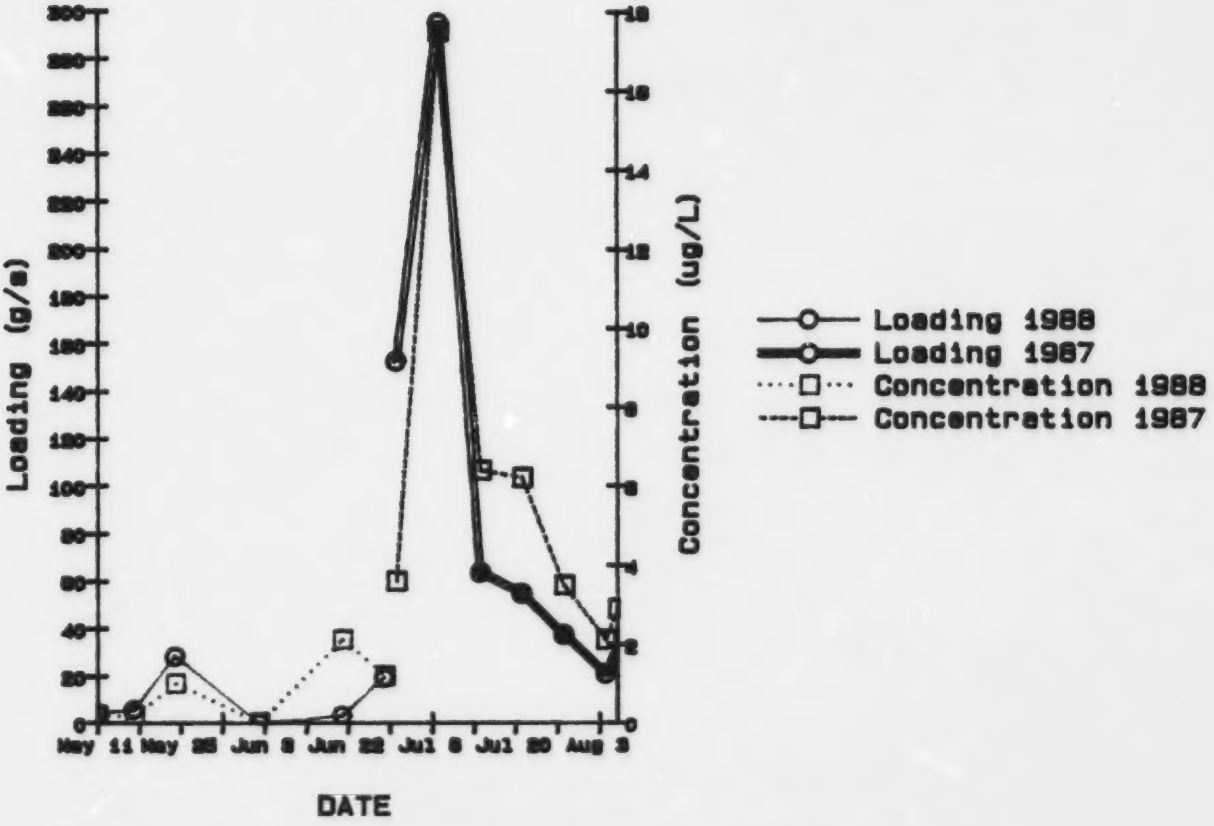
The pesticide, p,p'-DDE, was found in samples of emerald shiner, spottail shiner and yellow perch collected from the Yamaska River, (Table 7). Lindane was also found in spottail shiner taken from this river. Only the concentration of p,p'-DDE in the spottail shiner from the St. Francois River was found to exceed the detection limit.

3.4 Quality Control

All quality control correlations are shown in Appendix 8.

Figure 1: Loading of atrazine from the Yamaska River into the St. Lawrence River (1987-1988)

Figure 2: Loading of lindane from the Assomption River into the St. Lawrence River (1988)


Loading (g/s)
Concentration (ug/L)
May 11
May 25
Jun 8
Jun 22
Jul 8
Jul 20
Aug 3
DATE
Loading 1988
Loading 1987
Concentration 1988
Concentration 1987

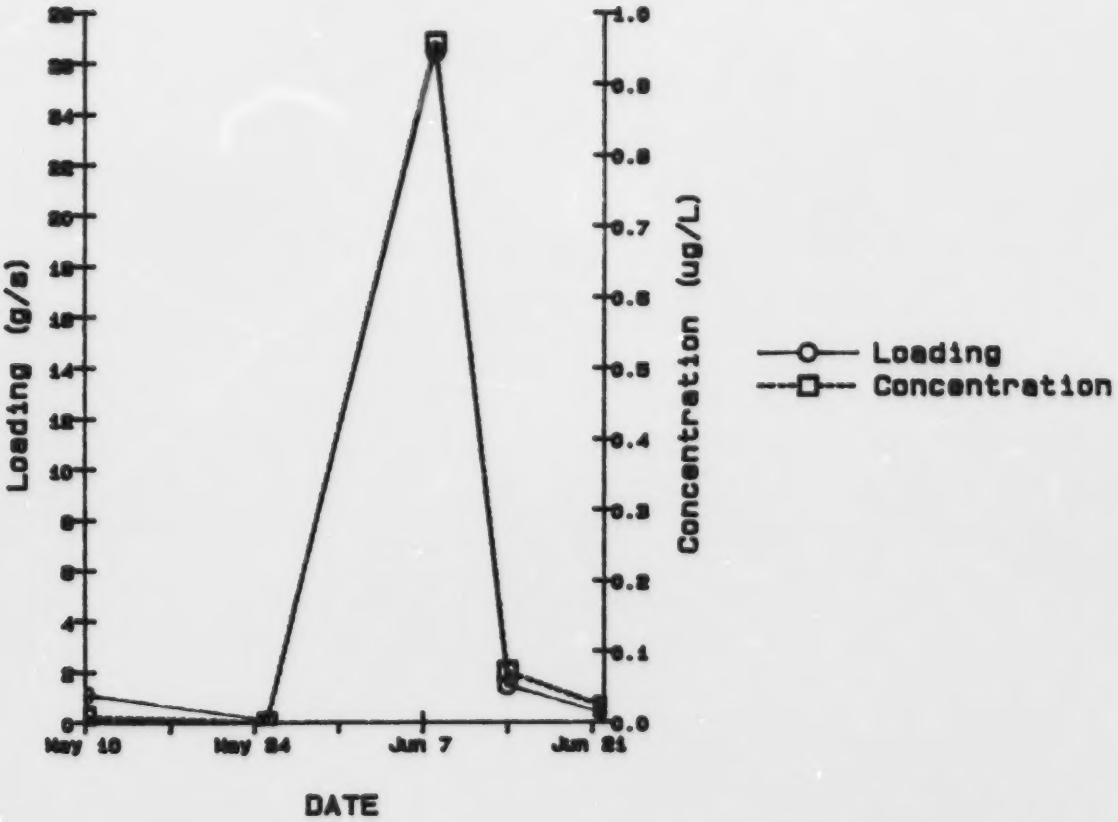

Loading (g/s)
Concentration (ug/L)
May 10
May 24
Jun 7
Jun 21
DATE
Loading
Concentration

Figure 3a: Variation of the concentration of atrazine in the Yamaska River vs time (1987-1988)

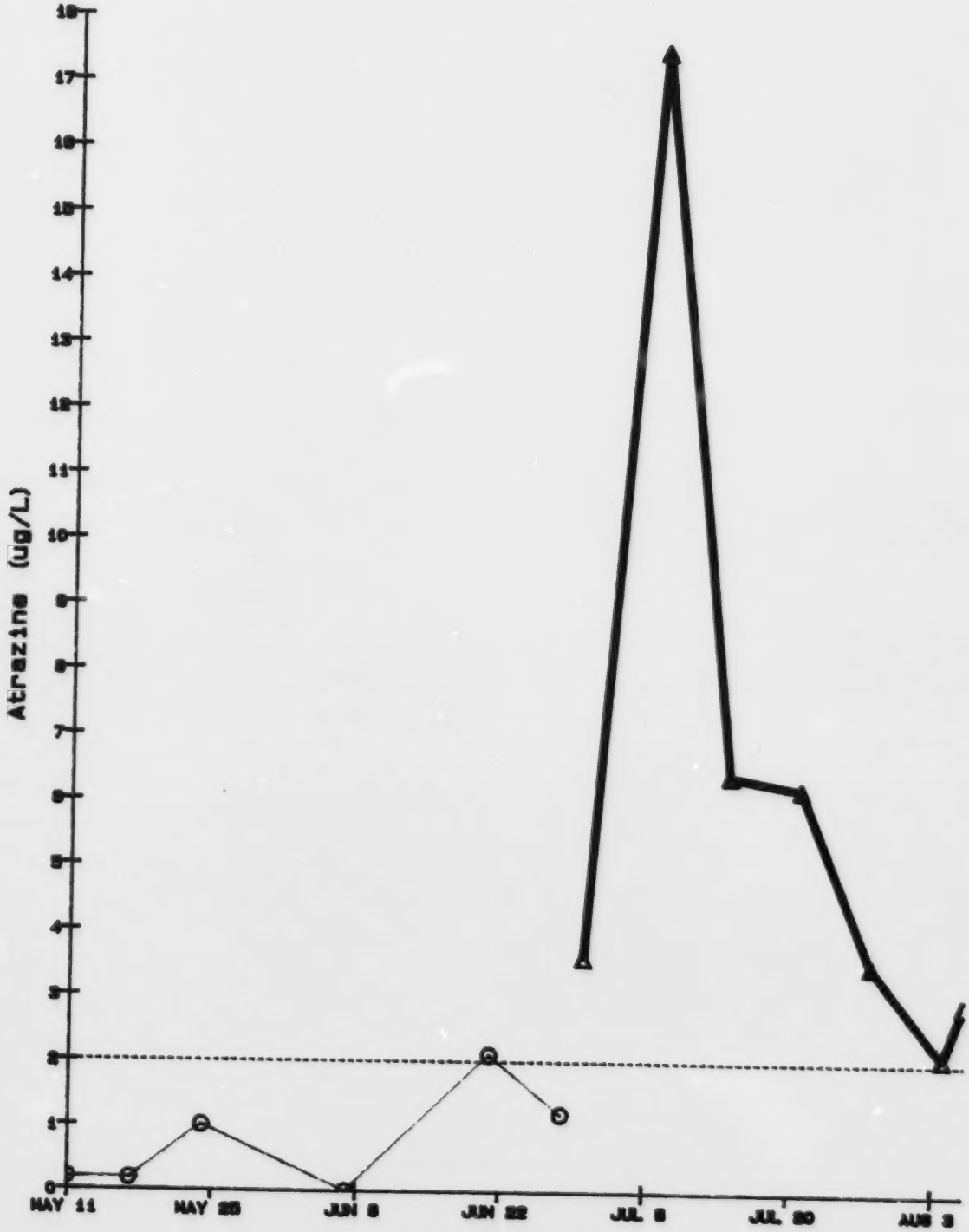
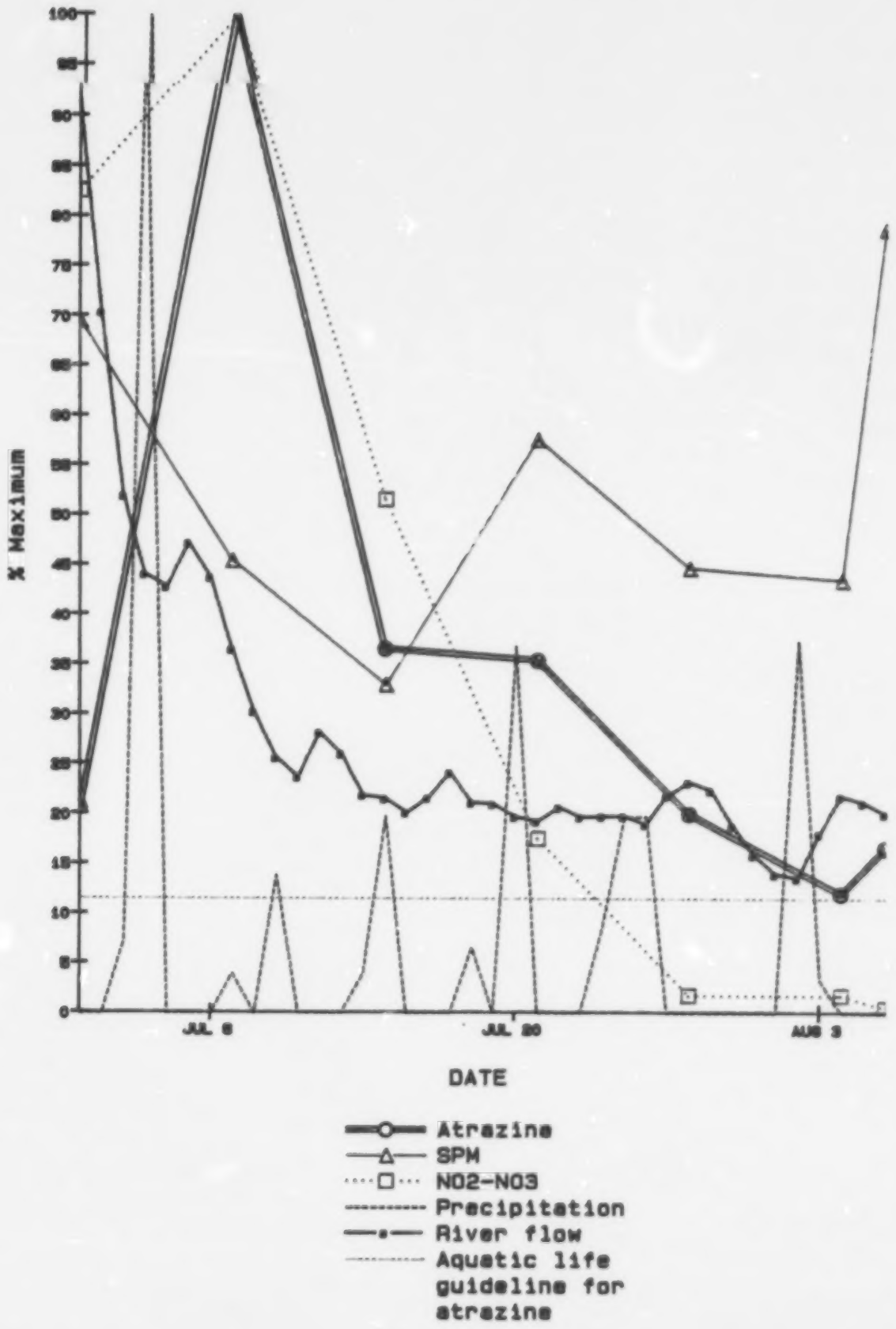

Atrazine (ug/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
MAY 11
MAY 25
JUN 8
JUN 22
JUL 6
JUL 20
AUG 3
DATE
Atrazine (1988)
Atrazine (1987)
Aquatic life guideline for atrazine

Figure 3b: Relative levels of atrazine, precipitation, river flow, SPM and NO_2-NO_3 in the Yamaska River (1987)


% Maximum
100
90
80
70
60
50
40
30
20
15
10
5
0
JUL 6
JUL 20
AUG 3
DATE
Atrazine
SPM
NO2-NO3
Precipitation
River flow
Aquatic life guideline for atrazine

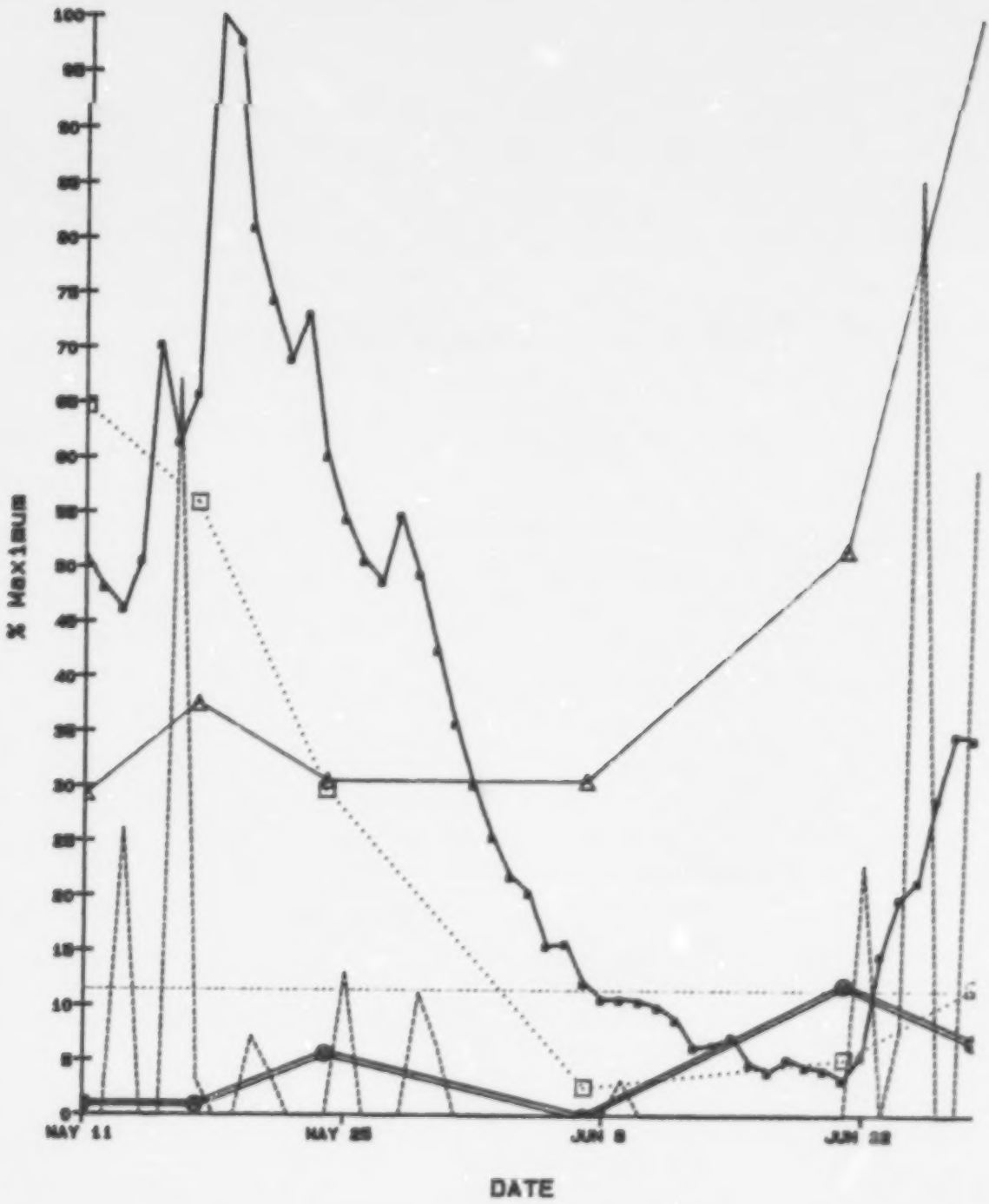
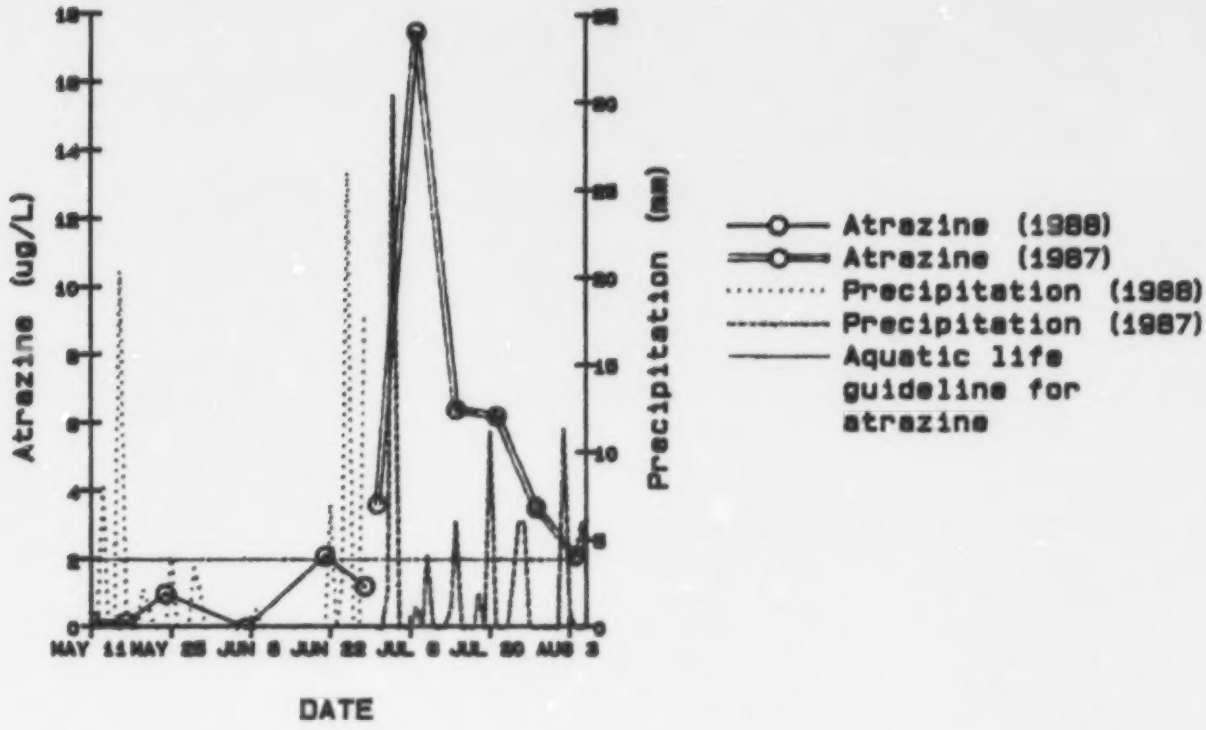

% Maximum
100
90
80
70
60
50
40
30
20
10
0
MAY 11
MAY 25
JUN 8
JUN 22
DATE
Atrazine
SPM
NO2-NO3
Precipitation
River flow
Aquatic life guideline for atrazine

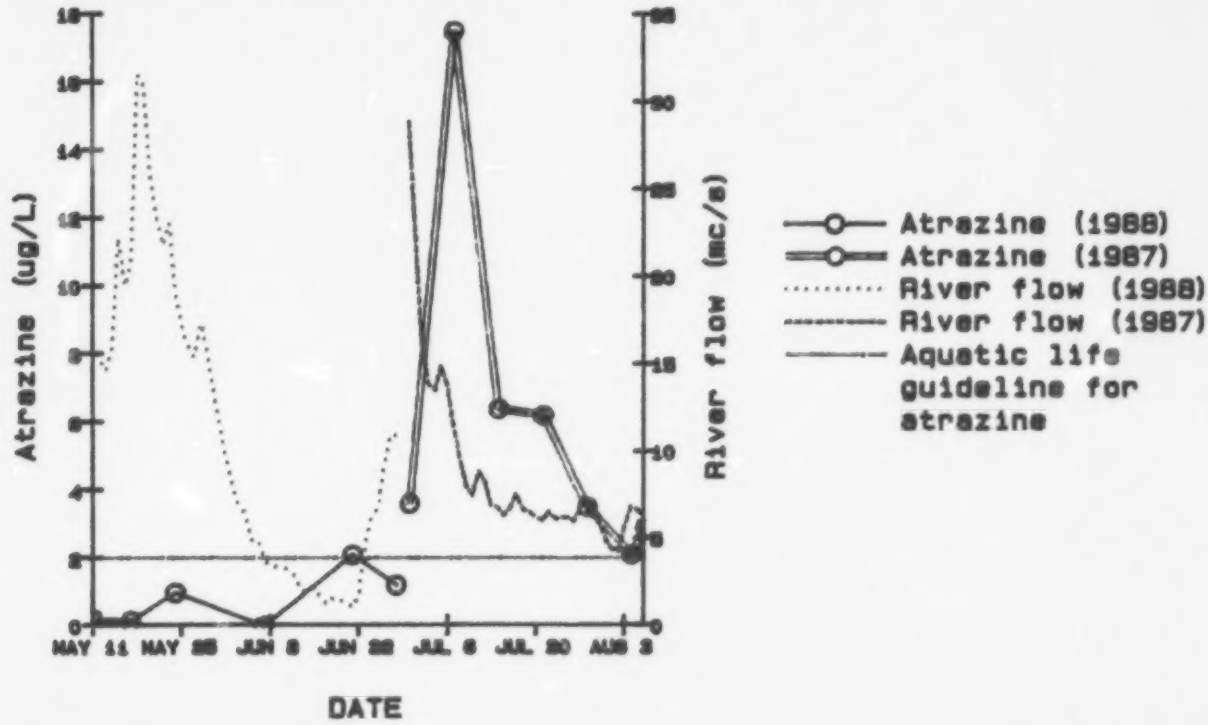
Figure 3d: Variation in the concentrations of atrazine and precipitation *vs* time in the Yamaska River (1987-1988)

Figure 3e: Variation in the concentrations of atrazine and river flow *vs* time in the Yamaska River (1987-1988)

Figure 3c: Relative levels of atrazine, precipitation, river flow, SPM and NO_2-NO_3 in the Yamaska River (1988)



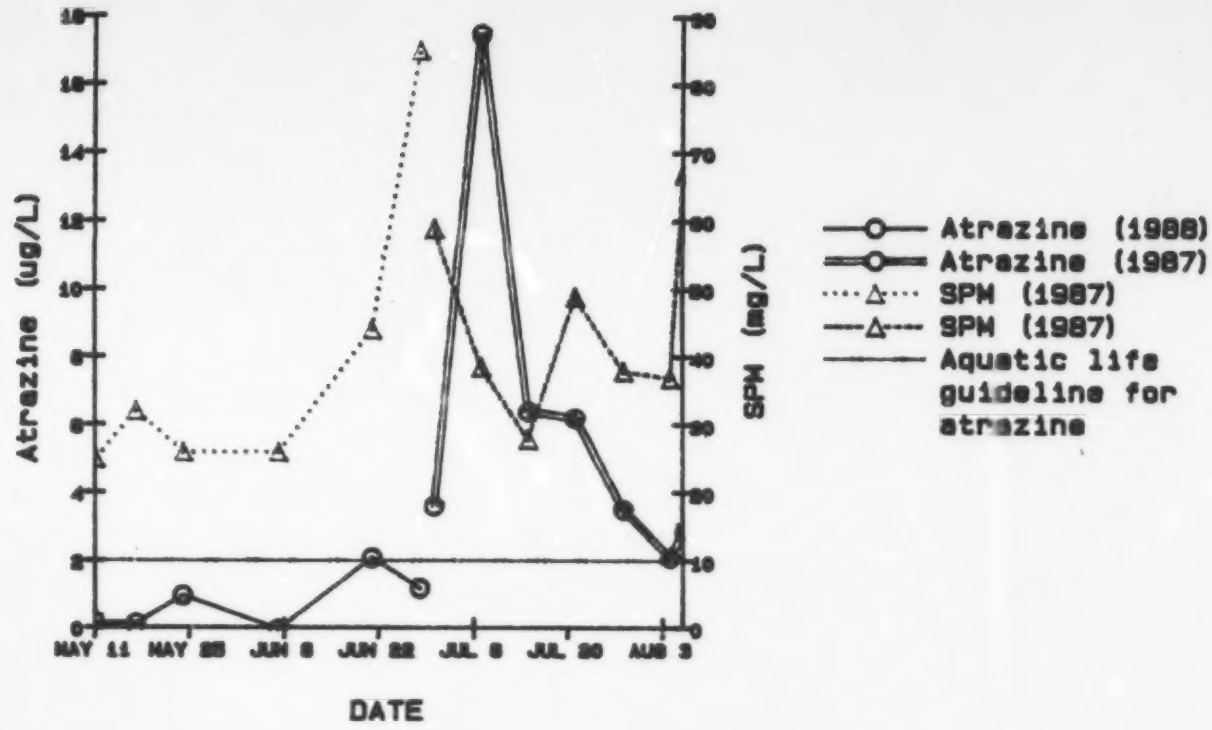
SR (1988): -0.142857
SR (1987): 0.357143



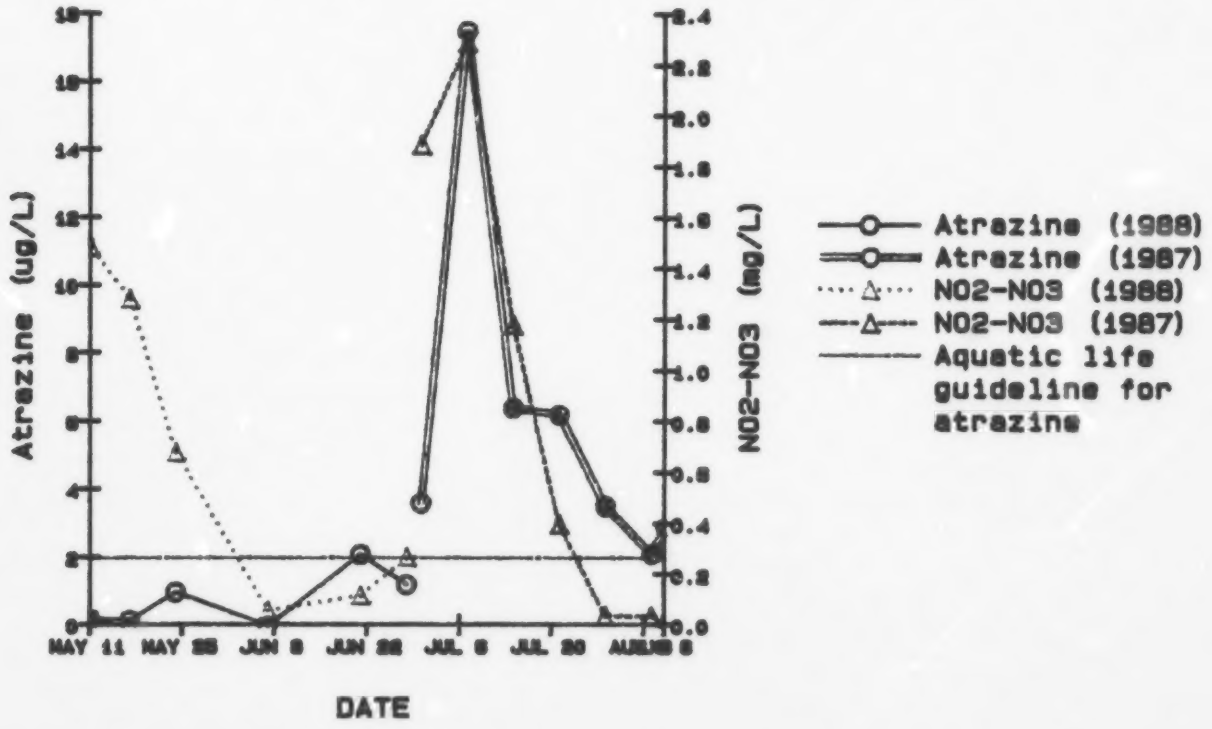
SR (1988): -0.695725
SR (1987): 0.774806

Figure 3f: Variation in the concentrations of atrazine and SPM *vs* time in the Yamaska River (1987-1988)

Figure 3g: Variation in the concentrations of atrazine and NO_2-NO_3 *vs* time in the Yamaska River (1987-1988)

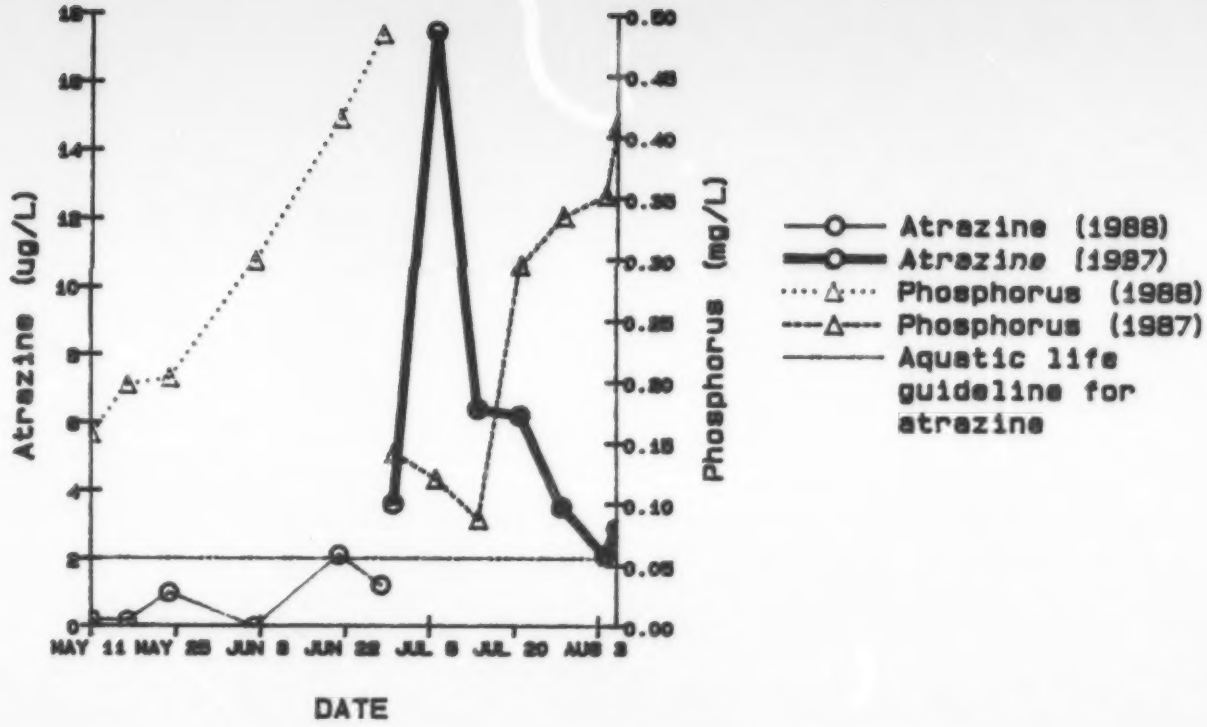


SR (1988): 0.579771
SR (1987): -0.142857



SR (1988): -0.085714
SR (1987): 0.828862

Figure 3h: Variation in the concentrations of atrazine and phosphorus vs time in the Yamaska River (1987-1988)



SR (1988): 0.542857
SR (1987): -0.892857

Figure 4a: Variation of the concentration of lindane in the Assomption River *vs* time (1988)

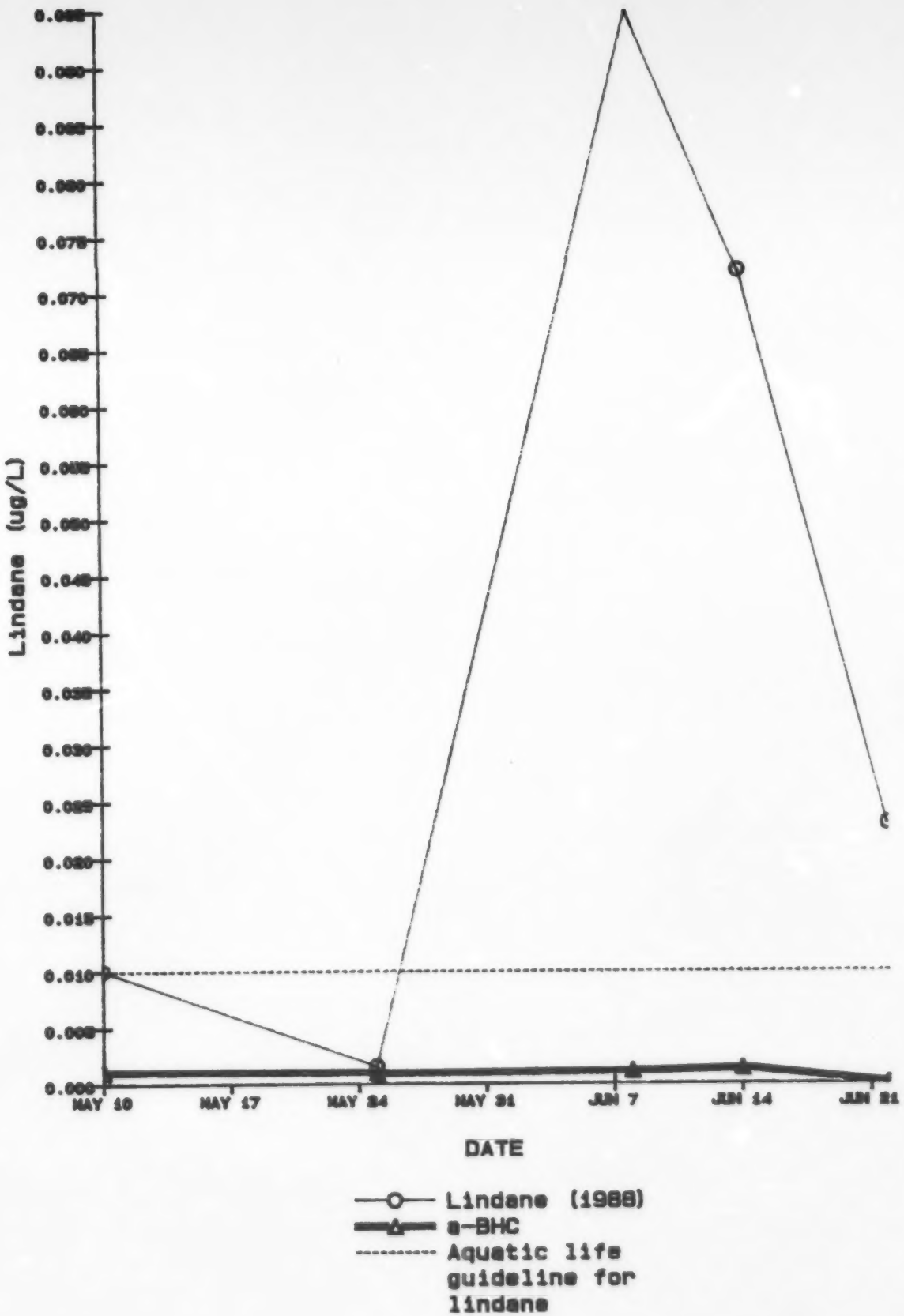

Lindane (ug/L)
0.010
0.000
MAY 10
MAY 17
MAY 24
MAY 31
JUN 7
JUN 14
JUN 21
DATE
Lindane (1988)
a-BHC
Aquatic life guideline for lindane

Figure 4b: Relative levels of lindane, precipitation, river flow, SPM and NO_2-NO_3 in the Assomption River (1988)

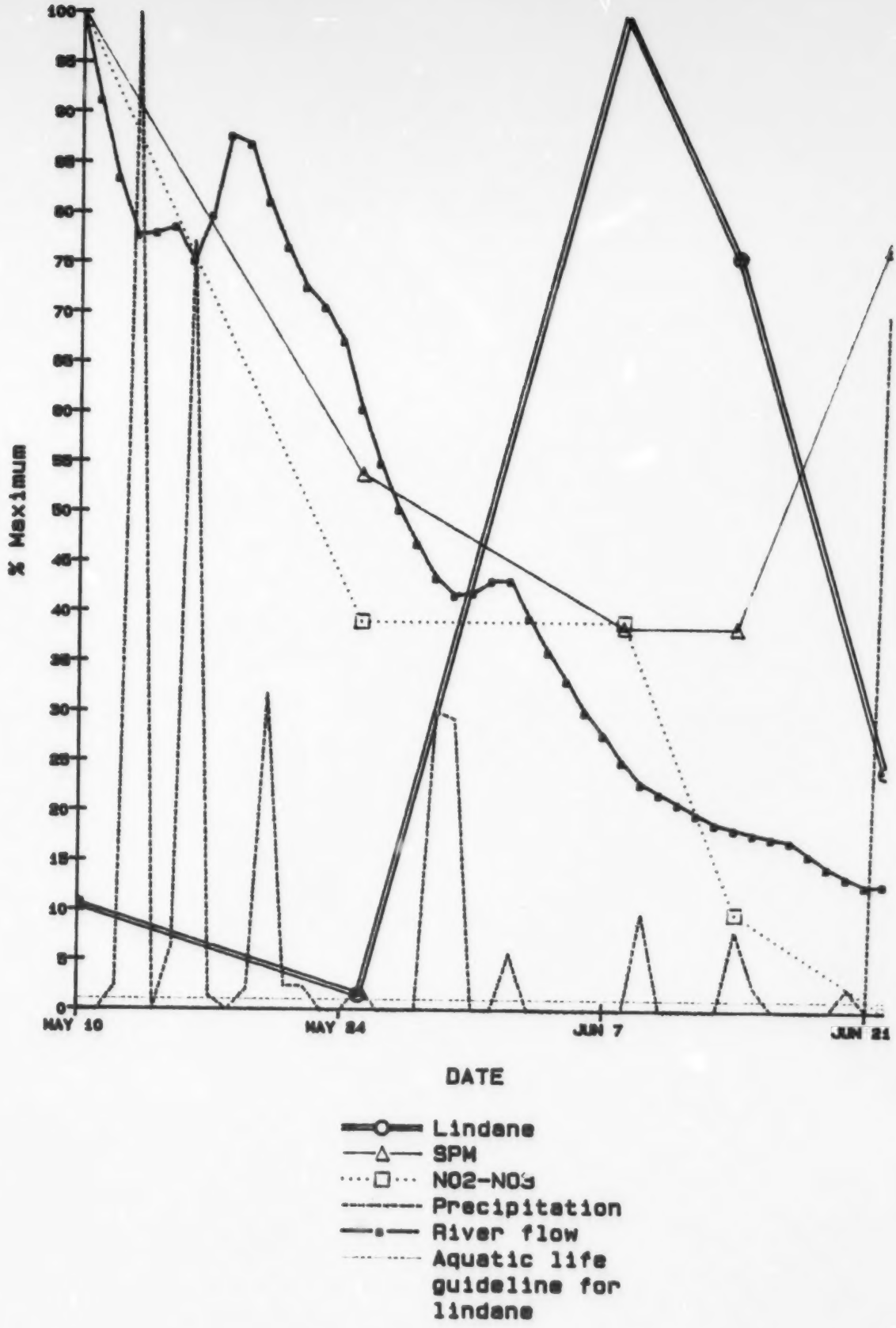
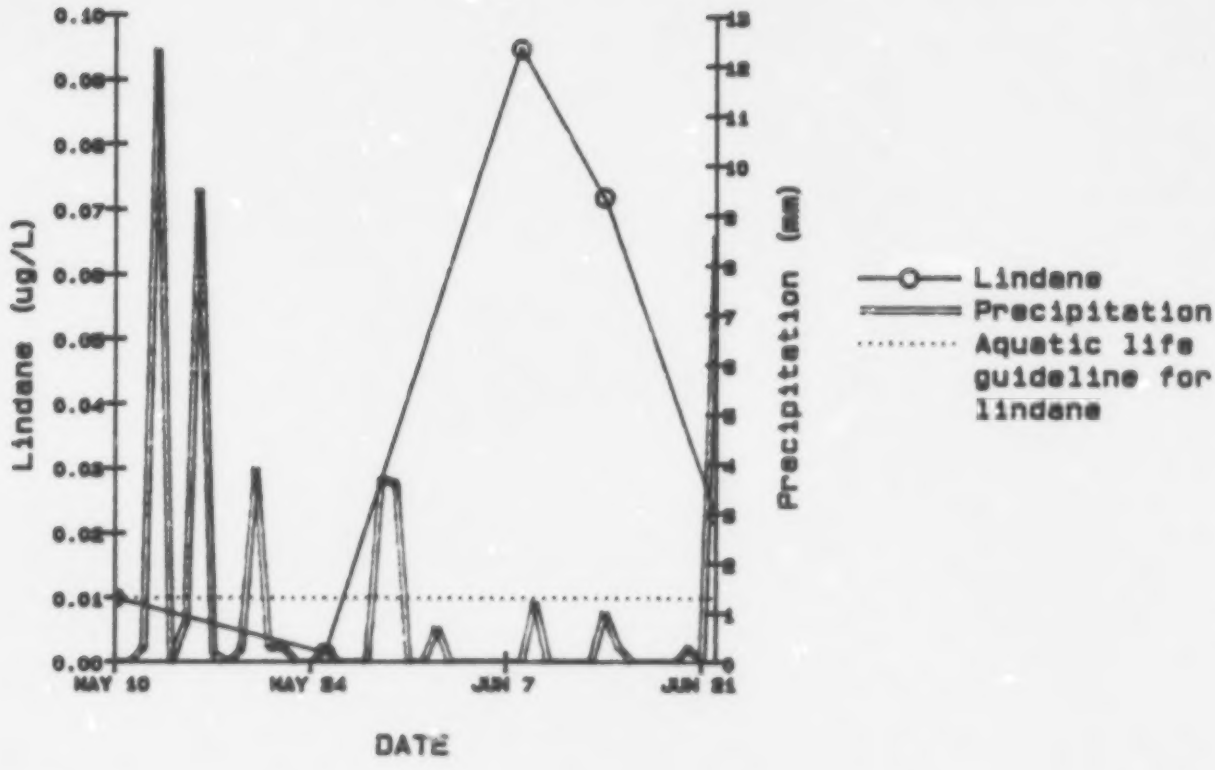
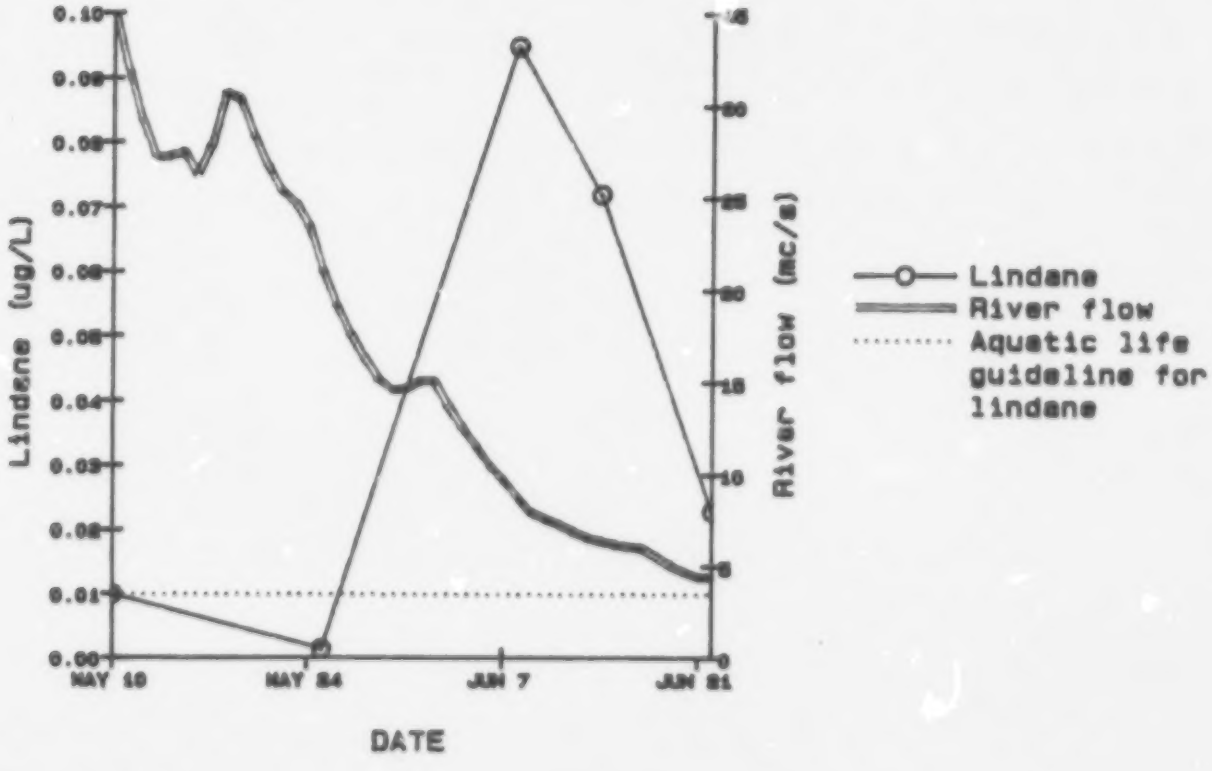

% Maximum
100
90
80
70
60
50
40
30
20
10
0
MAY 10
MAY 24
JUN 7
JUN 21
DATE
Lindane
SPM
NO2-NO3
Precipitation
River flow
Aquatic life guideline for lindane

Figure 4c: Variation in the concentrations of lindane and precipitation vs time in the Assomption River (1988)

Figure 4d: Variation in the concentrations of lindane and river flow vs time in the Assomption River (1988)


Lindane (ug/L)
Precipitation (mm)
MAY 10
MAY 24
JUN 7
JUN 21
DATE
Lindane
Precipitation
Aquatic life guideline for lindane

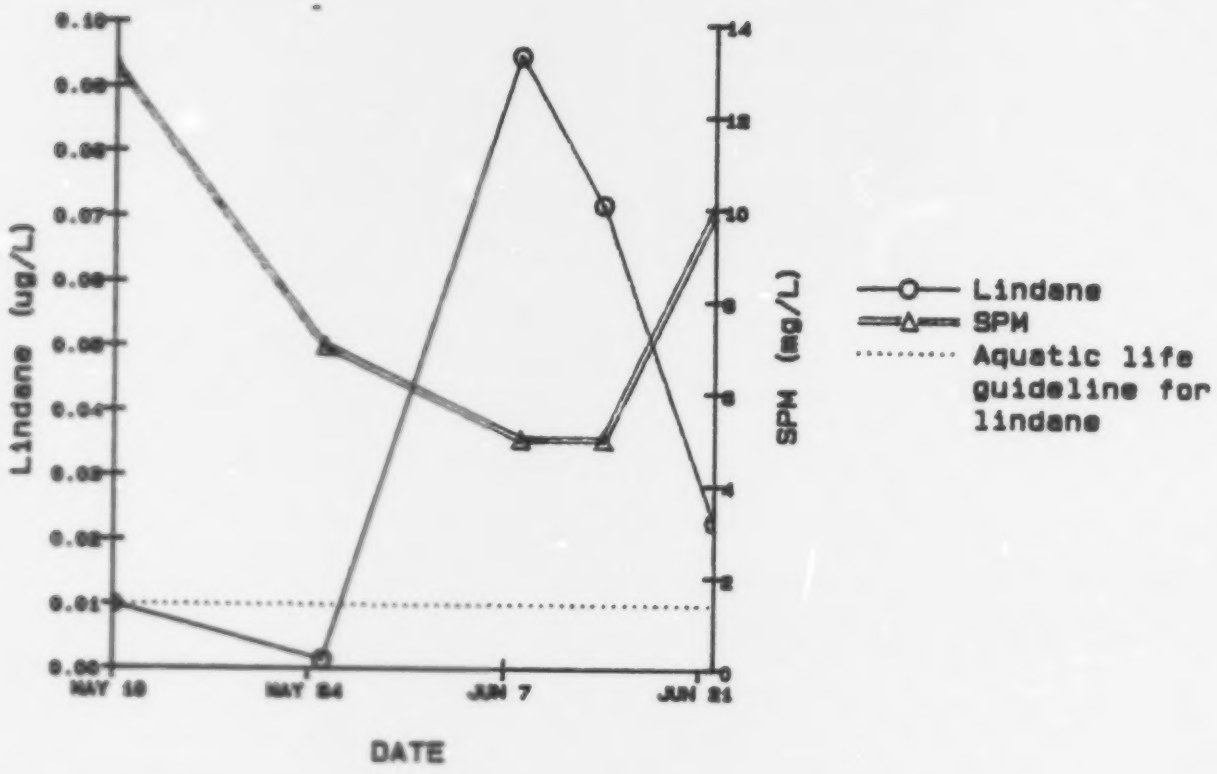
SR: -0.3


Lindane (ug/L)
River flow (mc/s)
MAY 10
MAY 24
JUN 7
JUN 21
DATE
Lindane
River flow
Aquatic life guideline for lindane

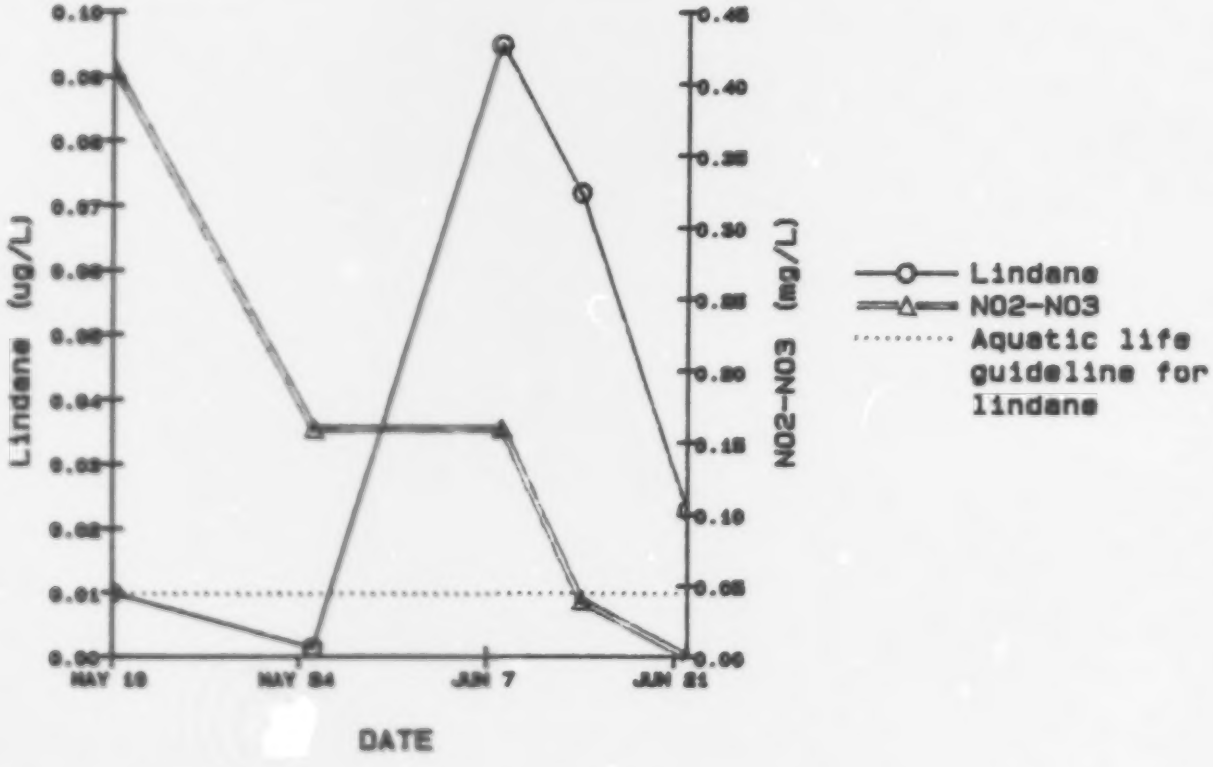
SR: -0.5

Figure 4e: Variation in the concentrations of lindane and SPM *vs* time in the Assomption River (1988)

Figure 4f: Variation in the concentrations of lindane and NO_2-NO_3 *vs* time in the Assomption River (1988)

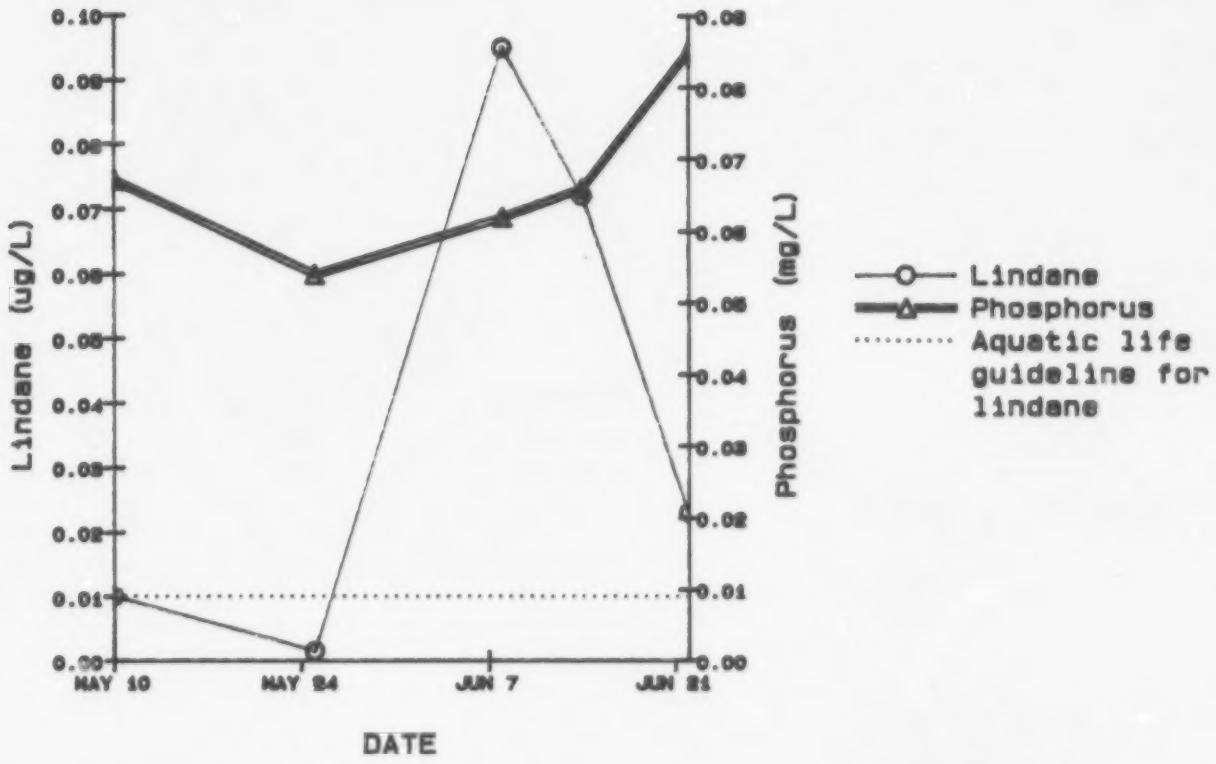


SR: -0.666886



SR: -0.307794

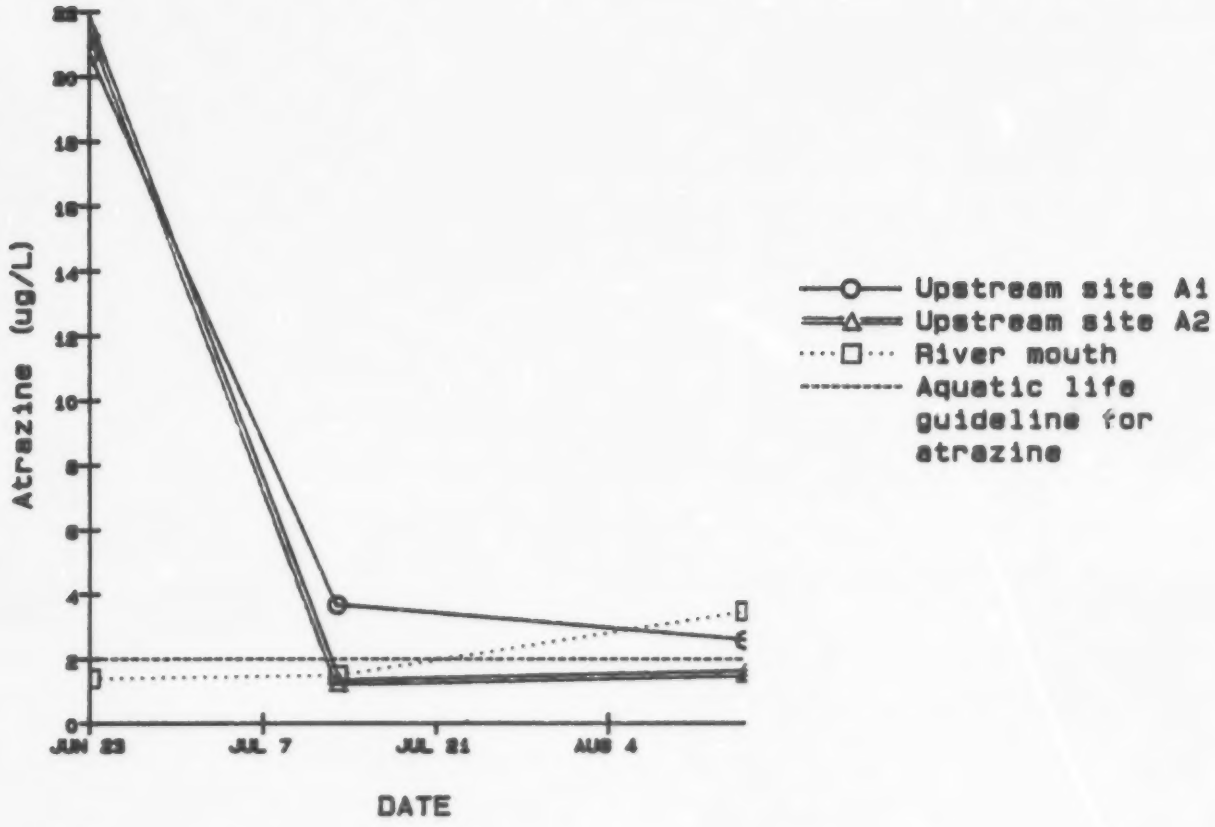
Figure 4g: Variation in the concentrations of lindane and phosphorus vs time in the Assomption River (1988)


0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Lindane (ug/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Phosphorus (mg/L)
MAY 10
MAY 24
JUN 7
JUN 21
DATE
Lindane
Phosphorus
Aquatic life guideline for lindane

SR: 0.1

Figure 5a: Variation in the concentration of atrazine in the St. Regis River *vs* time (1988)

Figure 5b: Variation in the concentration of diazinon in the St. Regis River *vs* time (1988)


Atrazine (ug/L)
JUN 23
JUL 7
JUL 21
AUG 4
DATE
Upstream site A1
Upstream site A2
River mouth
Aquatic life guideline for atrazine

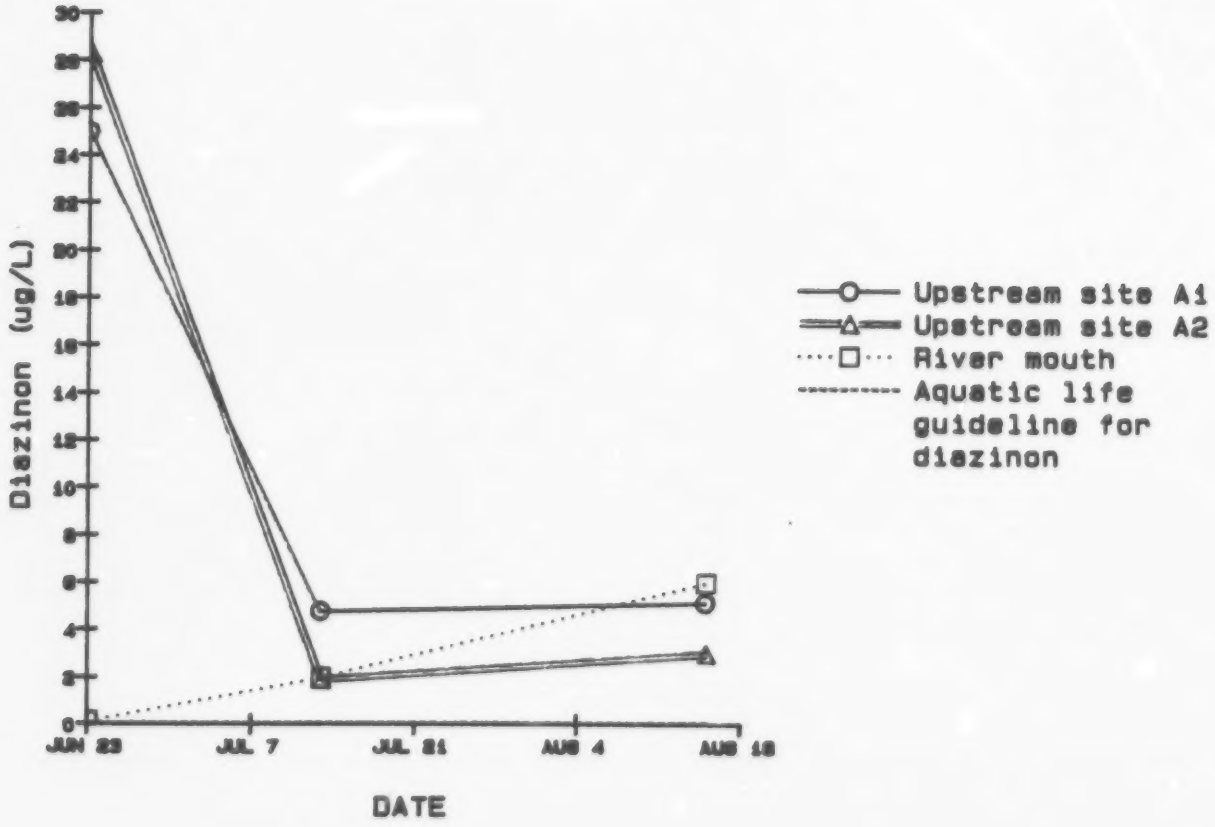
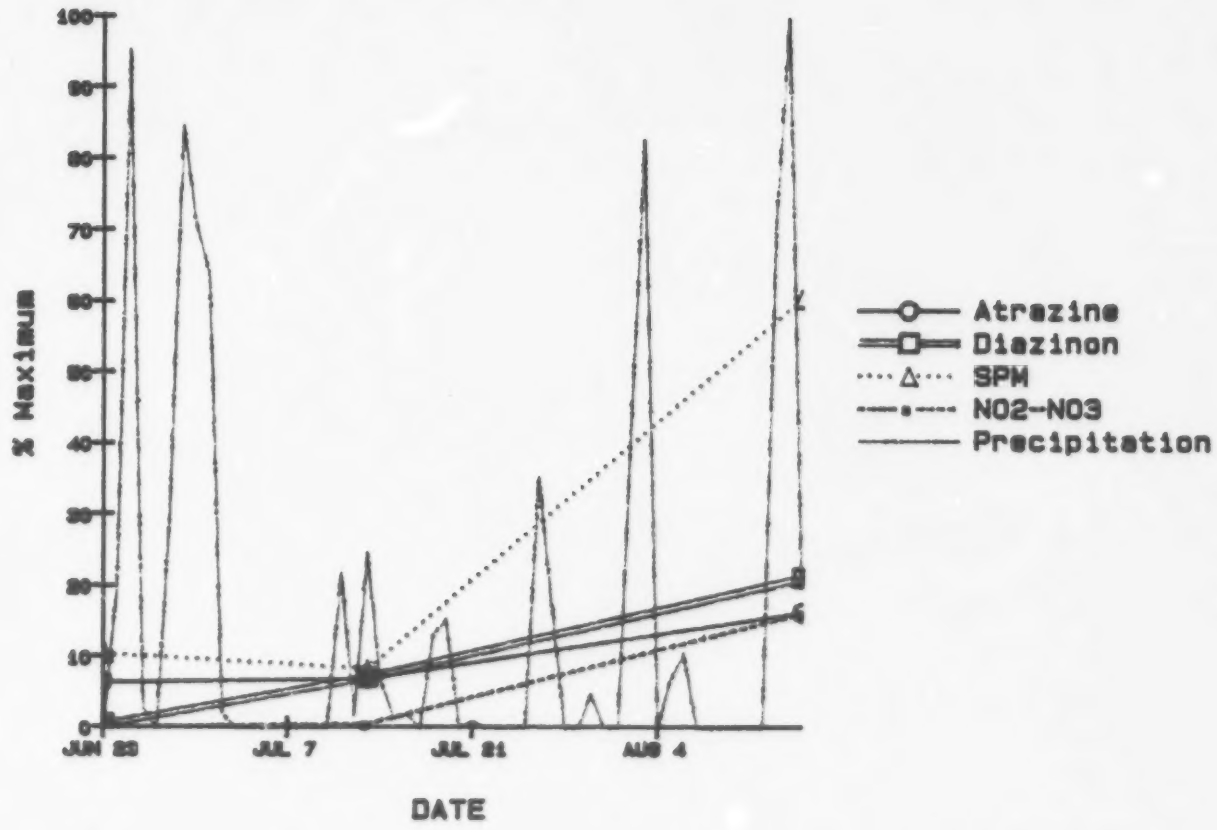

Diazinon (ug/L)
JUN 23
JUL 7
JUL 21
AUG 4
AUG 18
DATE
Upstream site A1
Upstream site A2
River mouth
Aquatic life guideline for diazinon

Figure 5c: Relative levels of atrazine, diazinon, precipitation, SPM and NO_2-NO_3 at the mouth of the St. Regis River (1988)

Figure 5d: Relative levels of atrazine, diazinon, precipitation, SPM and NO_2-NO_3 in the St. Regis River (1988) at site A1 upstream from the mouth


% Maximum
100
90
80
70
60
50
40
30
20
10
0
JUN 23
JUL 7
JUL 21
AUG 4
DATE
Atrazine
Diazinon
SPM
NO2-NO3
Precipitation

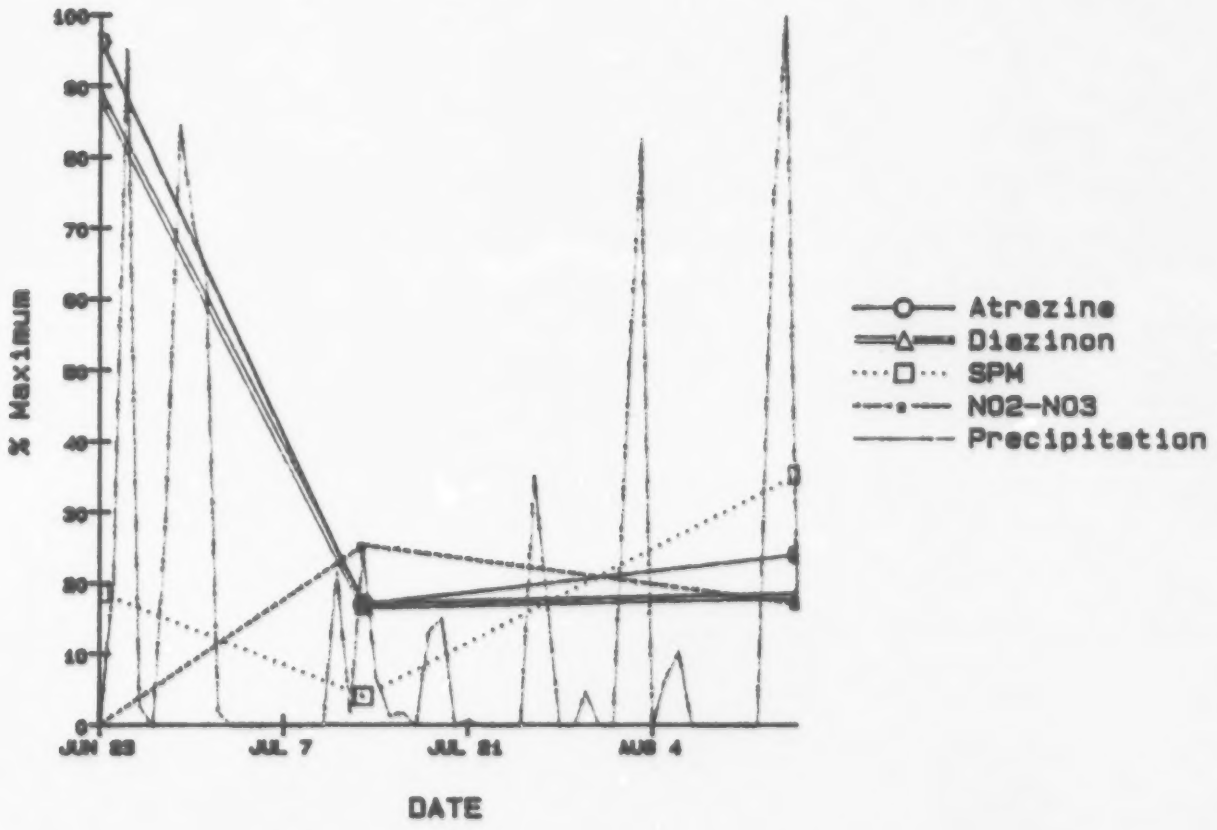

% Maximum
100
90
80
70
60
50
40
30
20
10
0
JUN 23
JUL 7
JUL 21
AUG 4
DATE
Atrazine
Diazinon
SPM
NO2-NO3
Precipitation

Figure 5e: Relative levels of atrazine, diazinon, precipitation, SPM and NO_2-NO_3 in the St. Regis River (1988) at site A2 upstream from A1

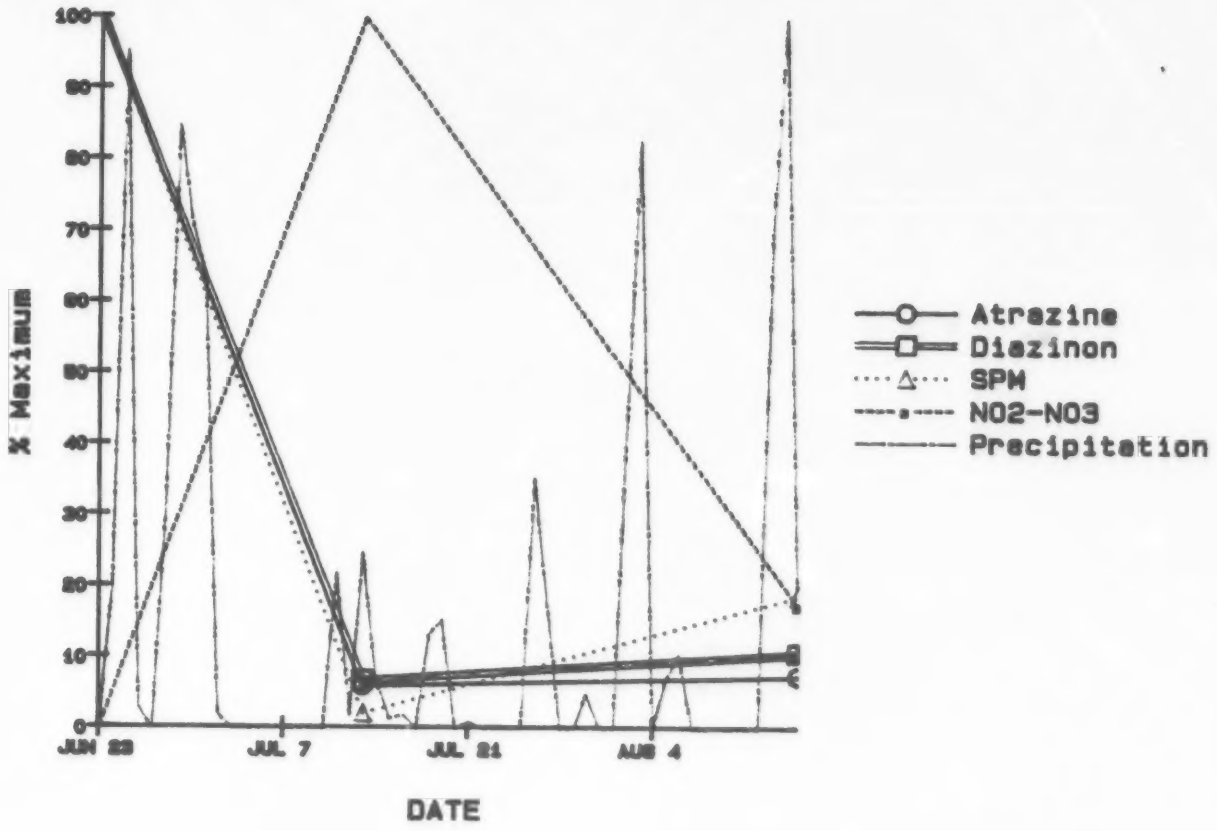
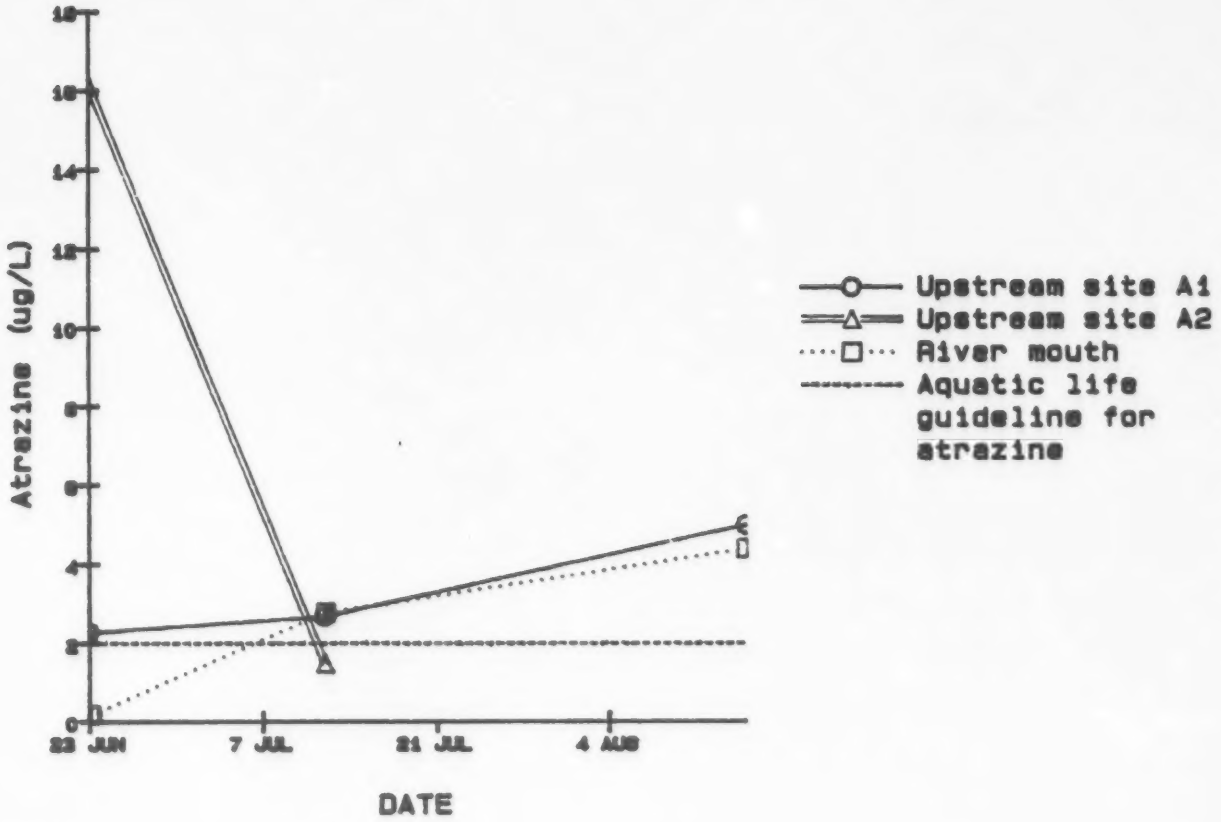

% Maximum
100
90
80
70
60
50
40
30
20
10
0
JUN 23
JUL 7
JUL 21
AUG 4
DATE
Atrazine
Diazinon
SPM
NO2-NO3
Precipitation

Figure 6a: Variation in the concentration of atrazine in the Tortue River *vs* time (1988)

Figure 6b: Variation in the concentration of diazinon in the Tortue River *vs* time (1988)


Atrazine (ug/L)
23 JUN
7 JUL
21 JUL
4 AUG
DATE
Upstream site A1
Upstream site A2
River mouth
Aquatic life guideline for atrazine

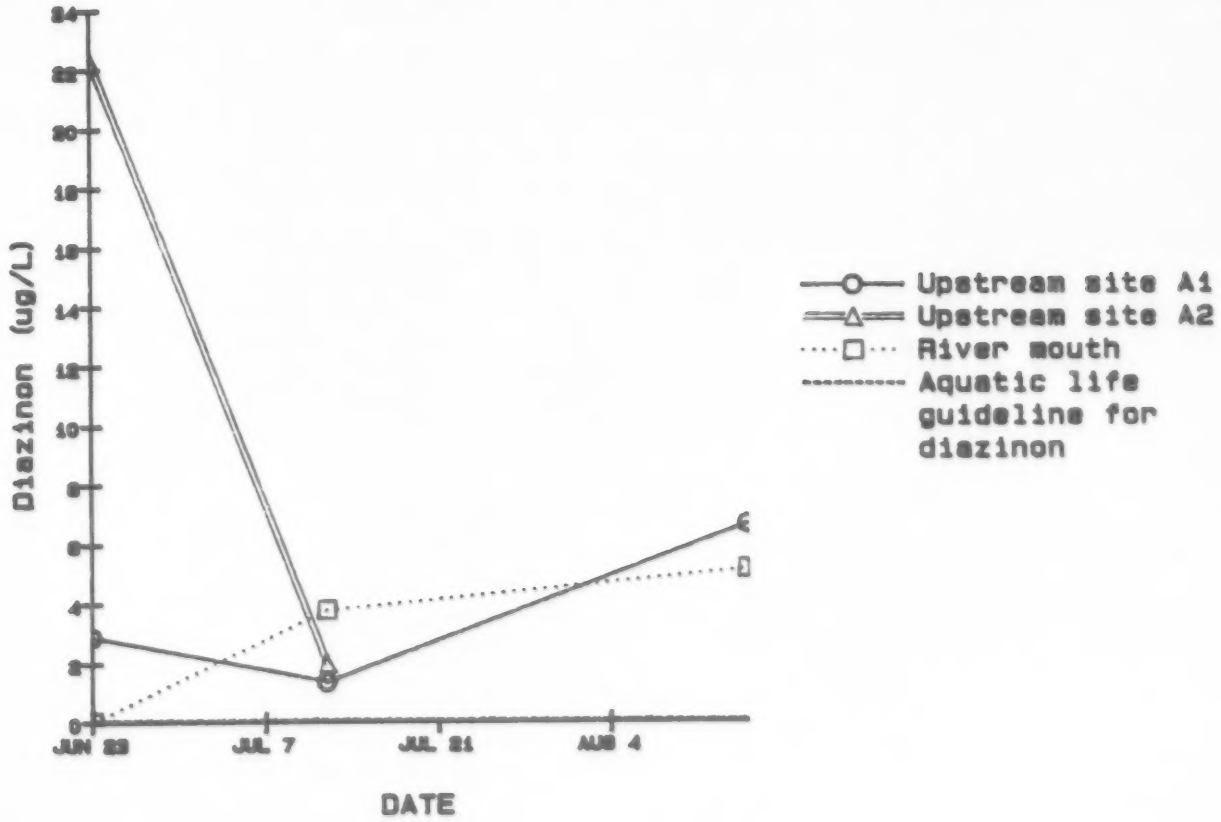
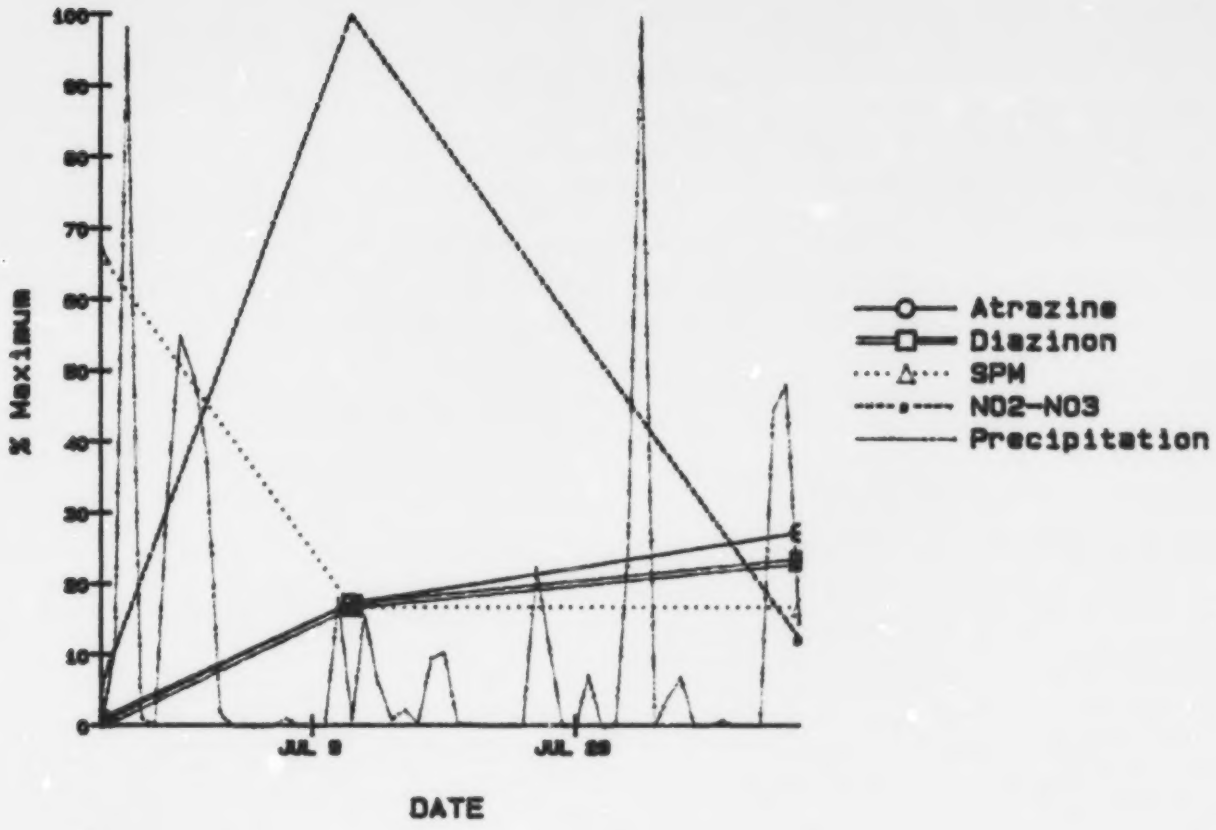

Diazinon (ug/L)
JUN 23
JUL 7
JUL 21
AUG 4
DATE
Upstream site A1
Upstream site A2
River mouth
Aquatic life guideline for diazinon

Figure 6c: Relative levels of atrazine, diazinon, precipitation, SPM and NO_2-NO_3 at the mouth of the Tortue River (1988)

Figure 6d: Relative levels of atrazine, diazinon, precipitation, SPM and NO_2-NO_3 in the Tortue River (1988) at site A1 upstream from the mouth


% Maximum
100
90
80
70
60
50
40
30
20
10
0
JUL 9
JUL 29
DATE
Atrazine
Diazinon
SPM
NO2-NO3
Precipitation

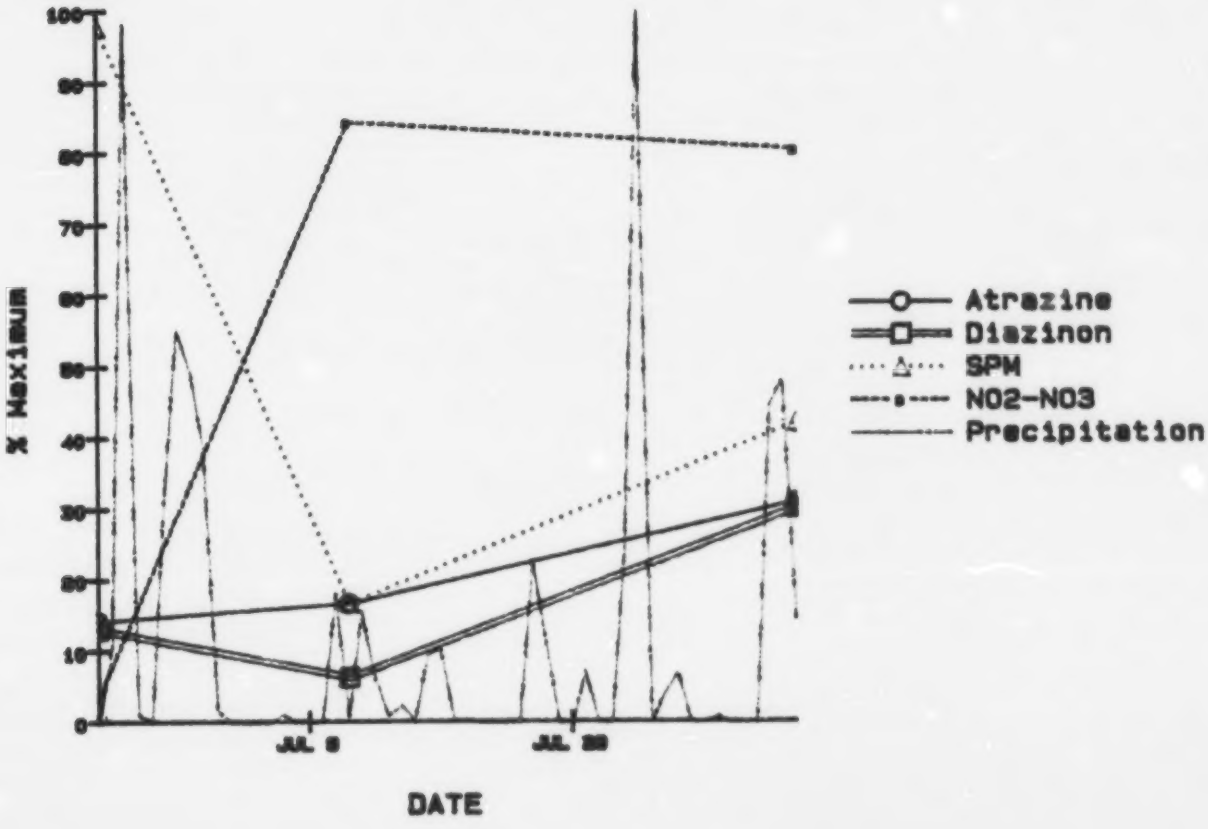

% Maximum
100
90
80
70
60
50
40
30
20
10
0
JUL 9
JUL 29
DATE
Atrazine
Diazinon
SPM
NO2-NO3
Precipitation

Table 6: Concentrations of pesticides found in water samples

River or Tributary	Date	Butylate ug/L	2,4-DP ug/L	2,4-D ug/L	Picloram ug/L	Alachlor ug/L	Metolachlor ug/L	Atrazine ug/L	Diazinon ug/L	a-BHC ug/L	Lindane ug/L
Guideline			4.000	4.00	29.00	not specified	78.00	2.0000	0.08	0.01000	0.01000
Yamaska	30-JUN-87			0.38	0.62		0.14	3.6000			
	07-JUL-87		0.193				0.16	17.5000			
	14-JUL-87		1.200				0.10	6.4000			
	21-JUL-87		0.750					6.2000			
	28-JUL-87		0.523					3.5333			
	04-AUG-87							2.1000			
man*	06-AUG-87							2.9000			
	14-OCT-87									0.00140	
Saint Francois	30-JUN-87							1.1000			
	07-JUL-87		0.960					0.5300			
	14-JUL-87		4.570					0.3200			
	21-JUL-87							0.2900			
	28-JUL-87		1.000					0.1900			
	04-AUG-87		1.400					1.6000			
man*	06-AUG-87							0.2300			
Yamaska	11-MAY-88							0.1900			
	17-MAY-88							0.1800	0.08		
	24-MAY-88						0.83	1.0000			
	07-JUN-88						0.36				
	21-JUN-88							2.1000			
	28-JUN-88						0.17	1.2000	2.20		
Yamaska Tributaries											
South	17-MAY-88							0.4400	0.20		
	28-JUN-88						1.10	2.9000	5.70		
Chibouet	17-MAY-88							0.6000	0.20		
	28-JUN-88						0.24	1.6000	2.40		
David	17-MAY-88							0.5100	0.20		
	28-JUN-88						0.13	1.2000	3.30		
Saint Francois	21-JUN-88							0.2500			
Saint Francois Tributaries											
Saint Germain	31-MAY-88							0.5000			
Aux Vaches	31-MAY-88							0.3000			
Assomption	10-MAY-88									0.00104	0.01000
	25-MAY-88									0.00097	0.00155
	08-JUN-88									0.00111	0.09580
	14-JUN-88									0.00133	0.07210
	22-JUN-88										0.02300
Assomption Tributaries											
Ouarou	14-JUN-88									0.00192	

*t trans chlordane
*c cis chlordane

(Table 6 continued)

River or Tributary	Date	p,p'-DDE ug/L	Dieldrine ug/L	a-endosulfan ug/L	°t chlordane ug/L	°c chlordane ug/L	p,p'-DDT ug/L	b-endosulfan ug/L
Guideline		0.00300	0.00400	0.02000	0.00600	0.00600	0.001000	0.0200
Yamaska	30-JUN-87							
	07-JUL-87							
	14-JUL-87							
	21-JUL-87							
	28-JUL-87							
	04-AUG-87							
man°	06-AUG-87							
	14-OCT-87					0.00050		
Saint Francois	30-JUN-87							
	07-JUL-87							
	14-JUL-87							
	21-JUL-87							
	28-JUL-87							
	04-AUG-87							
man°	06-AUG-87							
Yamaska	11-MAY-88							
	17-MAY-88							
	24-MAY-88							
	07-JUN-88							
	21-JUN-88							
	28-JUN-88							
Yamaska Tributaries								
South	17-MAY-88							
	28-JUN-88							
Chibouet	17-MAY-88							
	28-JUN-88							
David	17-MAY-88							
	28-JUN-88							
Saint Francois	21-JUN-88							
Saint Francois Tributaries								
Saint Germain	31-MAY-88							
Aux Vaches	31-MAY-88							
Assomption	10-MAY-88							
	25-MAY-88	0.00053						
	08-JUN-88							
	14-JUN-88							
	22-JUN-88							
Assomption Tributaries								
Ouareu	14-JUN-88							

°t trans chlordane
°c cis chlordane

(Table 6 continued)

River or Tributary	Date	Butylate ug/L	2,4-DP ug/L	2,4-D ug/L	Picloram ug/L	Alachlor ug/L	Metolachlor ug/L	Atrazine ug/L	Diazinon ug/L	a-BHC ug/L	Lindane ug/L
Achigan	14-JUN-88										0.00140
Saint Regis											
A1	23-JUN-88						0.50	20.7000	25.00	0.00174	0.01850
A2	23-JUN-88	0.71					0.52	21.5000	28.30	0.00192	0.00120
Mouth	23-JUN-88			1.20		0.28		1.4000	0.13	0.00146	0.00146
A1	13-JUL-88							3.7000.	4.80	0.00109	0.00460
A2	13-JUL-88							1.3000	1.90		
Mouth	13-JUL-88							1.5000	2.00	0.00137	0.00309
A1	15-AUG-88			0.46				2.6000	5.20	0.00177	0.01320
A2	15-AUG-88			0.49				1.6000	3.00		
Mouth	15-AUG-88			0.91				3.5000	6.00		
Saint Jacques											
mouth	23-JUN-88			0.61				1.4000	0.11	0.00172	0.00298
mouth	14-JUL-88							11.3000	19.70	0.00110	0.00419
mouth	15-AUG-88	2.00		3.20				0.5000	0.70	0.00212	0.00328
Tortue											
A1	23-JUN-88							2.3000	2.90	0.00223	0.00306
A2	23-JUN-88							16.1000	22.30	0.00229	0.00699
Mouth	23-JUN-88			0.22				0.2000	0.05	0.00251	0.00165
A1	12-JUL-88						0.15	2.7000	1.40	0.00148	0.07720
A2	12-JUL-88							1.5000	2.00		
Mouth	12-JUL-88						0.18	2.8000	3.80	0.00243	0.00250
A1	15-AUG-88							5.0000	6.70	0.00185	0.00299
Mouth	15-AUG-88	1.90		1.10				4.4000	5.20	0.00175	0.00118

*t trans chlordane
*c cis chlordane

River or Tributary	Date	p,p'-DDE ug/L	Dieldrine ug/L	a-endosulfan ug/L	*t chlordane ug/L	*c chlordane ug/L	p,p'-DDT ug/L	b-endosulfan ug/L
Achigan	14-JUN-88		0.00062					
Saint Regis								
A1	23-JUN-88							
A2	23-JUN-88	0.00074		0.00079				
Mouth	23-JUN-88				0.00055	0.00079		
A1	13-JUL-88							
A2	13-JUL-88							
Mouth	13-JUL-88							
A1	15-AUG-88			0.77000				
A2	15-AUG-88							
Mouth	15-AUG-88							
Saint Jacques								
mouth	23-JUN-88	0.00050						
mouth	14-JUL-88							
mouth	15-AUG-88					0.00088		
Tortue								
A1	23-JUN-88	0.01400		0.01980			0.016200	0.0100
A2	23-JUN-88	0.00282		0.06960			0.000513	0.0401
Mouth	23-JUN-88	0.00062						
A1	12-JUL-88	0.00079						
A2	12-JUL-88							
Mouth	12-JUL-88							
A1	15-AUG-88	0.00154		0.02940			0.001170	0.0351
Mouth	15-AUG-88							

*t trans chlordane
*c cis chlordane

Table 7: Concentrations of pesticides in SPM and bottom sediments

Station	Pesticide	Concentration ($ug\ g^{-1}$)
SPM		
Yamaska	atrazine	0.04
St. Jacques	α-BHC	0.002
	cis-chlordane	0.001
	trans-chlordane	0.002
	p,p'DDD	0.001
	p,p'DDT	0.001
St. Regis	α-BHC	0.022
	β-BHC	0.022
	cis-chlordane	0.008
	trans-chlordane	0.010
	p,p'-DDT	0.012
	p,p'-DDE	0.004
Tortue	α-BHC	0.004
	lindane	0.001
	cis-chlordane	0.006
	trans-chlordane	0.008
	p,p'-DDT	0.012
	p,p'-DDE	0.006
	2,4,5-T	0.040
Bottom sediment		
Yamaska	Atrazine	0.02
St. Jacques		
mouth	α-BHC	0.002
A1	α-BHC	0.002
	cis-chlordane	0.002
	2,4,5-T	0.01
A2	α-BHC	0.001

(Table 7 continued)

St. Regis		
mouth	α-BHC	0.008
	p,p'-DDE	0.004
	hexachlorobenzene	0.001
	2,4-DP	1.300
	2,4-D	1.100
	2,4,5-T	0.320
A1	α-BHC	0.014
	2,4-D	1.000
A2	α-BHC	0.002
	trans-chlordane	0.002
Tortue		
mouth	α-BHC	0.002
	cis-chlordane	0.004
	trans-chlordane	0.006
A1	α-BHC	0.002
	cis-chlordane	0.012
	trans-chlordane	0.018
	p,p'-DDT	0.001
A2	α-BHC	0.001
	cis-chlordane	0.001
	trans-chlordane	0.001
	p,p'-DDE	0.001
	2,4-D	0.04
Assomption		
	MCPA	6.000
	2,4-D	0.01

Table 8: Pesticides found in fish in the Yamaska and St. Francois Rivers in 1987

River	Pesticide	Date	Type of fish	Pesticide concentration (ug g^{-1}, wet weight)	No. samples
Yamaska (mouth)	p,p'-DDE	31 Jul 87	Emerald Shiner	0.007	
		31 Jul 87	Spottail Shiner	0.009	
		31 Jul 87	Yellow Perch	0.007	
		14 Aug 87	Spottail Shiner	0.010	
		7 Sept 87	Spottail Shiner	0.006	
	lindane	7 Sept 87	Spottail Shiner	0.009	
St. Francois (mouth)	p,p'-DDE	31 Jul 87	Spottail Shiner	0.009	

4.0 DISCUSSION

4.1 Pesticides in the rivers of Quebec's agricultural basins

Of the group of 40 pesticides classed as priority by SAGE (1988) (Table 1), 18 were included in this study's analyses. These pesticides were chosen according to the priority list for each basin (SAGE, 1988). Twenty-two other pesticides not on the SAGE list were also analyzed for. A total of 22 pesticides were detected in the water, sediment and fish samples (Tables 6, 7 and 8). From this group of detections, the following pesticides were from the SAGE list: butylate, 2,4-D, picloram, metolachlor, atrazine, diazinon, malathion, α and β endosulfan and cis-and trans-chlordane. The remaining detections included 2,4-DP, 2,4,5-T, MCPA, alachlor, α and β BHC, lindane, DDE, DDT, DDD, hexachlorobenzene, pentachlorobenzene and dieldrin. The solubilities, soil coefficients, volatilities, persistences and other information concerning these detected pesticides are shown in Table 9.

4.1.2 WQG and Exceedances

The WQG (CCREM, 1987) are recommendations designed for the protection and enhancement of water uses. They are useful for assessing water quality issues and concerns as well as providing basic scientific information regarding the potential effects of water quality parameters on water uses in Canada. Furthermore,

these guidelines are of use for the formation of site specific water quality objectives accounting for local conditions (Wong, personal communication, 1989).

Compliance with the water quality objectives is directly related to the monitoring strategy used. In the present study, the sampling program was of a fixed frequency type, sampling taking place at roughly regular intervals, usually about one to four weeks. According to Valiela and Whitfield (1989), fixed frequency sampling is good for objectives based on long-term mean requirements, whereas for objectives based on minimum allowable concentrations, exceedance driven sampling is recommended. Exceedance driven sampling refers to a process by which the frequency of sampling is increased upon the event of non-compliance to the WQG and decreased again when this non-compliance subsides. The results presented in this report, therefore, should be considered to represent only a rough estimate of the pesticide contamination over the course of the sampling seasons, the duration of the exceedances in question not being specified.

Of the detections from the SAGE list, only four pesticides were found at concentrations in the water compartment above the WQG (Appendix 1). These were atrazine, diazinon, 2,4-DP and endosulfan. Three other pesticides, lindane, p,p'-DDE and p,p'-DDT, which were not on the list, were also found to exceed the

Table 9: Characteristics of detected pesticides (adapted from Pierce and Wong, 1988; Rao and Davidson, 1981; Kenaga, 1980; Cohen et al., 1984; McRae, 1989; SAGE, 1988; Environment Canada, 1989; Worthing, 1987, Dubois, 1979)

Pesticide	Class	SAGE P.L.	GMP P.L.	Solubility mg/L 25C	Koc	Kow	Vapour Press. mPa 20C	Persistence (water)	Persistence (sediment)	Leaching Potential
Carbamates										
Butylate	non ionic,mod.solub.	@	@	45	540		170(25C)	35d*	1-3 mo.	high
Phenoxyacids										
2,4-D	acidic	@	@	620	20+/-72	416-646	0.12	5d* (F)	1 we.-1 mo.	high
2,4-DP	acidic			350			negliq.(25C)			
2,4,5-T	acidic			150	53		700(25C)	4-6 mo.(90%)		
Picloram	acidic	@	@	430	17		0.082(35C)	2-4 yr.	>12 mo.	probable or known
MCPA	acidic			825	110		0.20	>1 yr.	<1 mo.	probable or known
Amides										
Alachlor	non ionic,high solub.			242	190		2.9(25C)	2 mo.		
Metolachlor	non ionic,high solub.	@	@	0.53(20C)	140		1.7		3-5 mo.	probable or known
Triazines										
Atrazine	basic	@	@	30(20C)	163+/-49	212-562	0.04	64d* (F)	3-12 mo.	probable or known
Organophosphates										
Diazinon	PO4 pesticide	@	@	40(20C)	570	1052	0.10	6 mo.- 1 yr.	>6 mo.	high
Malathion	PO4 pesticide	@	@	145			5.3(30C)			moderate
Organochlorines										
Hexachlorobenzene	non ionic,low solub.			0.035	3914		1.45			
DDE	non ionic,low solub.									
alpha BHC	non ionic,mod.solub.			10	3.6	3.6				
Lindane	non ionic,mod.solub.		@	7	3.9	3.5	5.6	266d* (L)		high
beta BHC	non ionic,high solub.			5		4.5				
Chlordane	non ionic,low solub.	@		0.1	21300		61(25C)	3-5 yr.	3-5 yr.	
DDT	non ionic,low solub.			0.0017	238000		0.025	>36 mo.(90%)		
DDD	non ionic,low solub.			0.005	85500					
Endosulfan	non ionic,low solub.	@		0.320(22C)			1200(80C)	<6 mo.		
Dieldrin	non ionic,low solub.			0.186(20C)	35600		0.40	>36 mo.(90%)		
Pentachlorobenzene	non ionic,low solub.			0.135	13000					

P.L. Priority List
@ found on priority list
* Half life
(F) Field
(L) Laboratory
(90%) 90% remaining in the environment

guidelines (Table 4). In total, the samples were analyzed for 40 pesticides (Appendix 1). Thus, according to the present guidelines, two herbicides and five insecticides are of concern or may have had an environmental impact on aquatic ecosystems for the 1987-1988 monitoring survey for the Quebec region.

The number of samples containing pesticide concentrations exceeding the aquatic life guidelines is noteworthy (Table 4). Taking the number of stations into account and the fixed frequency sampling program, atrazine in the Yamaska River; lindane in the Assomption River; and atrazine and diazinon in the St. Regis and Tortue Rivers were found to consistently exceed their respective WQGs. It is emphasized that this pesticide contamination varied within spatial and temporal parameters, that is, pesticides were found in certain rivers at certain sites on these rivers and at specific times of the year.

4.1.3 Loading of atrazine and lindane into the St. Lawrence River.

As shown in Figures 1 and 2, the temporal profiles for the loading of atrazine and lindane into the St. Lawrence River are very similar to the concentration profiles for these pesticides. One could assume, therefore, that the magnitude of river flow does not greatly effect the relative pesticide loading levels. The discharge from a given tributary is probably influenced by

the same factors which affect concentration, namely, time and magnitude of pesticide application, volume and duration of precipitation as well as over-spray and spills (Muir et al., 1978).

4.1.4 Pesticides in water, sediment and fish in the drainage basins of the St. Lawrence River

The river basins included in this study were chosen because they represent regions of intense agricultural activity in Quebec. Since the river basins are very different from each other in terms of climate, soil and sediment type (McRae, 1989) and physical and chemical parameters (Appendix 3), it was necessary to consider the pesticide contamination of each basin separately.

The following factors (depending on available information) have been discussed as playing possible roles in the detections found:

(i) pesticide application (amount, timing)
(ii) precipitation and river flow
(iii) inherent properties of the pesticide (solubility, Koc, Kow, volatility)
(iv) persistence
(v) leaching potential

The detections of pesticides were also compared to the concentrations of other non-point contaminants such as SPM, nitrates and phosphorus (Baker, 1985). The magnitude and variation of SPM concentration is important because the fate of a given pesticide or fertilizer varies according to its capacity to bind to particles (Pierce and Wong, 1988). Nitrates and phosphates are often applied concurrently with pesticides and have predictable behaviors in relation to rainfall events (Baker, 1985). It is not in the scope of this study to discuss the nutrients and SPM themselves, but merely to point out a few interesting relationships they may have with the pesticides which may warrant further investigation. It is noted that the variations are interpreted to identify trends which cannot be supported by any extensive statistical analysis other than simple Spearman Rho correlations.

In several river basins, the concentrations of certain pesticides were consistently above the WQGs on more than 50% of the sampling dates. In view of this, the following case studies were discussed in detail: atrazine in the Yamaska; lindane (and α-BHC) in the Assomption and atrazine and diazinon in the St. Regis and Tortue. The detections in the XAD-2 resin columns were very low and therefore were not discussed (Appendix 7).

4.1.4.1 Case studies of exceedances in the Yamaska, Assomption, St. Regis and Tortue Rivers

4.1.4.1.1 Atrazine in the Yamaska River

In 1982, atrazine made up 41.9 % of the pesticide sales in the Yamaska River basin (SAGE, 1988). This was the largest use of one pesticide in this area. Furthermore, atrazine is used exclusively on corn, which represents 38% of the crops grown (SAGE, 1988). This high use pattern invariably contributes to the number and magnitude of atrazine detections found in the water and sediment samples taken from this river (Tables 6 and 7).

Atrazine is applied to crop fields between late April and early June (Appendix 6). Despite the temporal overlap with the application period, the atrazine levels in the water in the 1988 sampling season (May and June) were relatively low (Figures 3a and Table 6). Also during this interval, only two major precipitation events took place (Figure 3d), one at the beginning and one at the end of the sampling period. If atrazine was applied in between these two rainfalls, it is possible that it remained in the soil compartment for the duration of the sampling season and did not enter the surface runoff. Low atrazine levels in the spring and early summer was also found by Muir et al. (1978) in a study of the presence of atrazine in the Yamaska River.

In the 1987 sampling season (July and August), the atrazine concentrations detected were much higher than in 1988. The peak concentration of atrazine was found in July, similar, temporally and in magnitude, to the findings of Muir et al. (1978) for the same river and time of year. This peak concentration followed a heavy rainfall event (Figure 3b and 3d), supporting the general belief that rain hastens pesticide entry into aquatic systems (Weber et al., 1981). The magnitude of this July peak was also very close to what has been found in other watersheds in Canada as well as the United States and Sweden (Frank et al., 1982; Schepers et al., 1980; Butler and Arruda, 1985 and Kreuger and Brink, 1988). The correlation between atrazine concentration and precipitation was low in both sampling years (Figure 3d) probably because of the interval of time between the precipitation event and the entry of runoff waters in to the surface waters.

The effects of the river flow rates were directly related to the precipitation levels. The flow peaks occurred two to four days after major rainfall events (Figures 3b and 3c). The effect of increased river flow rate on the concentration of atrazine seems to be that of dilution, possibly due to higher river levels. As shown in Figure 3e, the July (1987) peak of atrazine concentration was observed only after a drop in the river flow rate. In 1988, the river flow rates were high for most of the season concurrent with consistently low atrazine concentrations. The correlation between atrazine concentration and river flow was

relatively high and positive in the 1987 sampling season (Figure 3e). This was probably due to the co-occurrence of runoff entry into the river and the subsequent flow increase.

Although, atrazine was found at relatively high concentrations in the water of the Yamaska River (Table 6), it was detected to a minimal extent in the bottom and suspended sediment indicating an association with the water compartment (Table 7). Further, as shown in Figure 3f, the levels of atrazine found in 1987 correlate very little with the concentration of SPM, a situation not uncommon in nature since SPM levels tend to increase rapidly at the beginning of a precipitation event and peak before the maximum pesticide discharge (Baker, 1985). The pH of the Yamaska river ranged from 7 to 9 for the sampling season (Appendix 3), a condition which favors the mobility in water of soluble, basic pesticides such as atrazine (Weber et al., 1981). The positive correlation between atrazine and SPM in the 1988 sampling season may have been an artifact of the low precipitation (Figure 3f).

Atrazine is considered to be moderately persistent having a half-life about 20 to 100 days (Table 9). Atrazine once deposited in the soil could theoretically stay there, if unperturbed, for the duration of the summer. Perhaps this can explain the low basal levels of atrazine in the 1988 sampling season, supposedly before applied atrazine has been washed into the river.

The correlation between the temporal variations of atrazine and nitrite-nitrates is highly positive in the 1987 sampling season, but negligeable in the 1988 data (Figure 3g). The close positive correlation between atrazine and nitrates is unusual since normally they enter the runoff at different times (Baker, 1985). Nitrate concentrations usually peak during the falling portion of a hydrograph, while maximum concentrations of atrazine theoretically occur sooner, at the same time as peak flow (Baker, 1985). This deviation of our results from what is commonly found in the literature for atrazine and nitrates may be due to a "missed peak" because of the fixed frequency sampling system and/or a difference in application timing. The source of atrazine is mainly agricultural, whereas, nitrate can also issue from natural mineral sources as well as from municipal and industrial waste-waters, septic tanks, decomposition of sewage wastes and feedlot discharges (CCRZM, 1987).

Phosphorus levels correlated negatively with atrazine (Figure 3h). Phosphorus is used in agriculture in two forms, soluble and particulate, the latter is documented to bind tightly to sediment and to be released into the surface waters concurrent to erosion (Baker, 1985). A study done in rural Ontario indicated that 80% of the phosphorus entering the surface waters is particulate while 20 % is soluble (Baker, 1984). If a similar ratio exists for the Yamaska river basin, then one would expect the peaks of SPM and phosphorus to have a similar concentration pattern

opposite to that of atrazine. This was the case in the data collected in 1987 (Figures 3f and 3h).

The degradation products of atrazine, DEA and, were not included in the present study due to some contradictory findings in the literature. According to Ghassemi et al. (1981), metabolites do not contribute significantly to the presence of atrazine in the surface waters. Muir et al. (1978) documented that DEA was in some cases detected to the same order of magnitude as the parent compound. DEA also has a toxicity similar to atrazine and it has been documented to be more persistent (Sirons et al., 1973).

According to McRae (1989), atrazine has a high potential for leaching into groundwater. In the Yamaska River basin, much of the surface cover is sand and sandy loam, both being prone to leaching. The sub-surface parent material, however, was marine and lacoustrine clay and only the latter allows the passage of water to the aquifer. The lacoustrine clay was found at an upstream site of the Yamaska River (McRae, 1989). One could, therefore, suspect groundwater as a possible source of atrazine contamination to the sub-surface river systems, although, more studies would be needed to attest this point.

4.1.4.1.2 Lindane and α-BHC in the Assomption River

Both α-BHC and lindane were detected at the mouth of the Assomption River and at the mouths of the Ouareau and Achigan tributaries on all sampling dates (May to June). Neither of these contaminants were on the SAGE (1988) list, therefore no pesticides sales data were available. Alpha-BHC is not registered for use in Canada (Appendix 1). Although a breakdown of the sales of lindane in Quebec was not available, it has been documented that only 0.6% of the lindane sold in Canada was purchased in Quebec (Environment Canada/Agriculture Canada, 1987). Of this amount, 66% was used for the treatment of livestock (beef cattle, horses, goats, sheep or swine) and 33% was used for seed treatment. In the Assomption River basin, lindane, in combination with diazinon and captan, is mainly used as a seed treatment, (Dagenais, personal communication, 1989). A possibility of livestock treatment remains since there is a large swine population in this area, however, more information would be needed to confirm this.

Lindane (from the pre-treated seeds and the livestock) would probably be entering the soil in the spring, concurrent with the application time. Deposition of aerially transported (in rain and snow) lindane and α-BHC can take place throughout the year. In North America, only lindane (γ isomer) is registered for use as an insecticide. Other countries use technical grade BHC which

consists of 66 % α-BHC, 12 % BHC, 12 % β-BHC and 6 % BHC (Environment Canada, 1989). Both α-BHC and lindane are very common contaminants of precipitation in Canada and in other countries, the α isomer usually exceeding the levels of the γ isomer (Strachan, 1985 and 1988). During the 1988 sampling season in the Assomption River, the lindane levels varied significantly while the α-BHC levels stayed low. The low α-BHC levels were probably due to foreign sources, whereas, the lindane contamination most likely originated in Canada.

The lindane concentration peak in early June followed a small precipitation peak and there was little correlation between the lindane and precipitation levels (Figures 4a, 4b and 4c). This indicates that lindane from a spring or early summer application may have been washed into the surface waters at this time. The maximum concentration of lindane did not occur at the same time as the peak flow (the correlation between these two variables being moderate and positive), which may have been due to the dilution effect of higher river levels (Figure 4d).

According to Environment Canada (1989) and Karickoff (1981), partitioning of lindane to sediments is considered a relatively minor process. This, in addition to the fact that lindane was not found in the sediments of this river basin, suggests that lindane is mainly associated with the water compartment, thus, its presence in the surface waters. Furthermore, the results show a

negative correlation between lindane and SPM concentrations.

The basal levels of α-BHC and lindane detected in the Assomption River water could also have been due to the relatively long persistence these pesticides as well as their aerial transportation. The half-life of lindane is about nine months (Rao and Davidson, 1981). A slightly longer persistence time could be predicted for α-BHC since it is known to be more stable than lindane (Environment Canada, 1989).

Pesticides which are used beneath the soil, such as those utilized for seed treatments have a higher leaching potential than those applied to foliage (McRae, 1989). In the Assomption River basin, much of the soil parent material is of a marine which is impervious to leaching. The upper part of the basin, however, has fluvialglacial parent material which does facilitate passage of water and pesticides to underground aquifers. Part of the lindane contamination could, therefore, have been due to a leakage of groundwaters in to the surface waters.

At the end of May in the Assomption River basin, a small rainfall event took place (Figure 4b). On the sampling date following this precipitation peak, the lindane levels increased drastically and the nitrites-nitrates concentration leveled off suggesting that the rainfall caused both contaminants to enter the surface runoff at this time (Figure 4f).

Phosphorus, 80% of which may be in the soil-binding particulate phase tends to peak very early in a hydrograph, similar to suspended sediment (Baker, 1985). As shown in Figures 4e and 4g, phosphate does vary in a way similar to the SPM, since they both increased on the first and last sampling dates. This suggested that much of the phosphorus in the system was soil bound in contrast to the soluble, non-soil binding lindane.

4.1.4.1.3 Atrazine in the St. Regis and Tortue Rivers

Small river monitoring may, in certain cases, key out the source of the pesticide contamination. The identification of this source becomes more difficult for larger bodies of water. In the St. Regis and Tortue Rivers, three points were sampled, one at the mouth and two upstream, therefore, a comparison of contamination at different locations can be made.

In the St. Regis and Tortue River basins, atrazine accounted for 61.2 and 9.9% of total pesticides sales, respectively, in 1982 (SAGE, 1988). In line with this usage pattern, atrazine was detected at higher concentrations in the St. Regis as compared to the Tortue.

Atrazine is applied from late April to early June (Appendix 6). The major precipitation event which occurred on June 22 in this area (Aubin, personal communication, 1989) probably

contributed to the peaks of atrazine concentration at sites A1 and A2 in the St. Regis River, the atrazine having been applied to the fields earlier in the season (Figures 5d and 5e). Since the rainfall event took place only one day before the June 23 sampling date, it is possible that the contamination had not yet reached the river's mouth (assuming that the source of contamination was upstream). On the July and August sampling dates for the St. Regis River, the concentrations of atrazine were relatively low (1 to 4 ug L^{-1}) at all sites along the river probably because atrazine was not applied over this interval.

In the Tortue River, the situation is similar to that found in the St. Regis. The atrazine concentration peaked in June at the A2 sampling site, whereas, it remained relatively low on all other sampling dates and sites (1 to 5 ug L^{-1}) (Figure 5a). Most likely, the June 22 precipitation event caused the peak the next day. One difference between the two river basins was that in the Tortue, the contamination seemed to be more localized to site A2, whereas in the St. Regis it was apparently spread out over site A1 and A2.

According to Baker (1985), nitrate concentrations tend to peak in the falling portion of a hydrograph, while soluble pesticides peak earlier. In the St. Regis River, this was seemingly the case, however, it is difficult to know exactly where the peaks were since there are only three sampling dates,

spaced at intervals of one month. The atrazine concentration peaked at sites A1 and A2 in June, while the nitrates peaked in July at the same sites, most predominantly at site A2 (Figures 5d and 5e). This pattern seems to roughly follow the statements of Baker (1985) although more sampling points would be required to prove this. A similar situation was apparent in the Tortue River A2 site (Figure 6d).

SPM concentrations generally tend to increase rapidly at the beginning of a precipitation event, while atrazine should peak later (Baker, 1985). At site A2 in the St. Regis and at the mouth and site A1 of the Tortue, the SPM is high immediately following the rain event (on June 22) (Figures 5d, 5e and 6d) in line with Baker's hypothesis. At site A2 of the St. Regis (Figure 5e) and Tortue Rivers (Table 6 and Appendix 3), the SPM peak coincides with the atrazine peak, indicating a possible source of erosion and pesticide contamination at these upstream sites. At the mouth of the St. Regis River, concentrations of both SPM and atrazine were low but increasing over the sampling season, suggesting dilution of upstream contamination. The St. Regis A1 site is characterized by low SPM and atrazine over the course of the season except for the pesticide peak in June. Either the SPM peak was missed due to the sampling program or the atrazine contamination is from upstream and did not enter the surface waters at this site. At the mouth and site A1 of the Tortue, there are SPM peaks in June concurrent with relatively low

atrazine levels. This indicates the A2 site as the sole source of pesticide contamination in this river.

4.1.4.1.4 Diazinon in the St. Regis and Tortue Rivers

As compared to the sales of atrazine in the St. Regis and Tortue River basins, the sales for diazinon are relatively low, 0% and 1.6%, respectively (SAGE, 1988). Late May to mid June, mid July and all of August are the most common application periods for the crops grown in these river basins (Appendix 6). The crops necessitating diazinon application constitute 4 and 5.2 % of the crops grown in these areas, respectively (SAGE, 1988). These crops include the following: tobacco, beans, fruit and fruit trees, carrots, cucumbers, lettuce, onions, green peas and tomatos.

The insecticide diazinon is soluble and has a moderate Koc value indicating a presence mainly in the water fraction (Table 9). According to Weber et al.(1981), however, diazinon, a phosphate pesticide, should readily complex with the clay in soils. As shown in Figures 5c, 5d, 5e, 6c and 6d, diazinon concentrations do not seem to correlate with SPM levels. It may be that there is very little clay in these soils and, therefore, diazinon would act in a similar way to atrazine as described above.

4.1.4.2 Other detections

4.1.4.2.1 Carbamates

4.1.4.2.1.1 Butylate

Butylate was found in the water of the St. Regis, St. Jacques and Tortue Rivers. Butylate represented 15.3 and 1.3 % of the pesticide sales in the St. Regis and Tortue River basins, respectively, in 1982 (SAGE, 1988). Similar sales data were not available for the St. Jacques River. Butylate is applied to crops from late April to late May and is usually used with atrazine against the weeds associated with corn. Corn represents 21.9 % of the crops grown in the St. Regis basin and 11.3 % in the Tortue. One could presume a low to moderate usage of butylate in the St. Regis and Tortue basins in view of the above.

The detection in the St. Regis River immediately followed a rainfall event which took place on June 22 (Table 6. Aubin, personal communication, 1989). Due to the soluble nature of butylate and its intermediate Koc value, it is probable that the majority of this pesticide would be washed out with the surface runoff and/or evaporated due to its high volatility, hence the detection (Table 9). The August detection in the St. Jacques and Tortue Rivers may have been due to a late application or a spill which would then have been washed into the river by the

precipitation event prior to that sampling date (Figure 6c).

Butylate is non-ionic and soluble and has a high potential for the contamination of groundwater (McRae, 1989). Groundwater may, therefore, have been a source of contamination, although more information about the groundwater itself and the nature of the soil would be need to prove this hypothesis.

4.1.4.2.2 Phenoxyacid Herbicides

4.1.4.2.2.1 2,4-D

According to SAGE (1988), 2,4-D constituted 1.4%, 1.2% and 2.4% of the pesticide sales in the Yamaska, St.Regis and Tortue River basins respectively in 1982. Sales data for the St. Jacques River Basin was not available. The herbicide 2,4-D is used on a wide variety of crops including cereals, grasses, corn, tobacco and strawberries which together make up the majority of the crops grown in all these basins (SAGE, 1988). It has also been reported that Hydro-Québec uses 2,4-D to clear vegetation (Varfalvy and Séguin, 1987). From the above, one could envisage that 2,4-D is used moderately in the above river basins which may partially explain the minimal findings in the water and sediment (Tables 6 and 7).

The application period for 2,4-D extends from late April to

early May (Appendix 6). As shown in Table 6, the only detection of 2,4-D in the Yamaska River was on June 30, 1987, a sampling date which followed a major precipitation event. Since this herbicide is acidic and has a high solubility it is very likely that it is associated with the water compartment. The persistence of 2,4-D is relatively low (half-life of five days in the field, Table 9). It would be reasonable to say, therefore, that the detection was due to a recent application even though this is inconsistent with the above application period. In the days before the major precipitation event there was a smaller rainfall which may have wet the soil, increasing the soil moisture value and decreasing losses due to volatization since 2,4-D has been known to form non-volatile soil complexes with soil water (Smith, 1982; Grover et al., 1985; Gile, 1983). SAGE (1988) has documented that 47 % of 2,4-D is present in the air and 48% in the water. This partitioning may partly explain the very low frequency of detection. The June 23 detections of 2,4-D in the St. Regis could be the result of a recent application (application period from mid April to early June). The detections of 2,4-D in mid August in the Tortue river may have been due to a late application which has occurred in the past in other areas (Nicholaichuk and Grover, 1983). 2,4-D was also found on the June 23 and August 15 sampling dates in the St. Jacques River. The first of these detections was probably due to a recent application and rainfall, whereas the latter detection could have been due to a spill and/or late application.

The herbicide 2,4-D was also found in the bottom sediments of the St. Regis and Tortue Rivers. Although, this is unusual for a soluble, acidic pesticide such as 2,4-D, perhaps pesticide usage in these areas was concentrated and recent.

According to McRae (1989), 2,4-D has a high potential to leach into groundwater. In view of the very short persistence of this chemical, one could predict that it would not stay in the groundwater long enough to cause significant contamination.

4.1.4.2.2.2 2,4-DP and 2,4,5-T

Sales and application data for 2,4-DP and for 2,4,5-T were not available. In Canada, however, 2,4-DP is registered for use only in combination with 2,4-D, although 2,4-D can be used alone (Agriculture Canada, personal communication, 1989). 2,4-DP was found in the water of the Yamaska and St. Francois Rivers on several sampling dates in July and early August of 1987 (Table 6). Presence in the water compartment is expected of these pesticides since they are highly soluble and acidic (therefore mobile in water at normal pH). These dates of detection are somewhat removed from the application interval of 2,4-D and the most recent major rainfall event took place more than a week preceding (Figure 3d). The highest detections in both rivers, however, took place on the July 14 sampling date, possibly indicative of a late summer application.

The phenoxyacid herbicide, 2,4,5-T, is acidic, has a high solubility, low Koc and a persistence value of four to six months (Table 9). This herbicide was found in the bottom sediments of the Assomption, the St. Regis and the St. Jacques Rivers and in the SPM of the Tortue River. The relatively long persistence of 2,4,5-T may explain its presence in the sediment.

4.1.4.2.2.3 Picloram

Picloram is often used in a mixture with 2,4-D and TCA (SAGE, 1988; Varfalvy and Séguin, 1985). Not surprisingly, therefore, picloram was detected on the same sampling date as 2,4-D (30 June 1987, Table 6) in the Yamaska River. Picloram has no set application interval and can be applied throughout the season. It is used to control the infestation of small trees or shrubs (SAGE, 1988). Similar to 2,4-D, picloram is acidic and has a high solubility indicating an association with water and, hence, its detection solely in the water compartment. In contrast to 2,4-D, however, picloram can have a long persistence in water (two to five years) (Table 9).

According to SAGE (1988) and McRae (1989), picloram is able to travel through soil and contaminate groundwater. The above detection, therefore, may have been due to a recent application or an earlier contamination from groundwaters entering the surface waters. The precipitation event preceding the detection

may have caused a raising of the aquifer and a consequent leakage into surface waters (McRae, 1989).

4.1.4.2.2.4 MCPA

MCPA accounted for 4% of the pesticide sales in 1982 in the Assomption River Basin (SAGE, 1988). This herbicide was detected in the bottom sediments collected from the mouth of Assomption River on July 29, 1988 (Table 7). MCPA is acidic, has a high solubility, a low Koc and is very persistent. This last characteristic probably accounted for its presence in the sediments. MCPA is a registered compound and is applied to fields from late May to late June (Appendix 6).

4.1.4.2.3 Amides

4.1.4.2.3.1 Alachlor

Alachlor was detected at the mouth of the St. Regis River on the June 23 sampling date at a concentration of 0.28 ug L^{-1}. Alachlor was banned in Canada in 1985 and it has a persistence of two months. The detection may, therefore, have been due to an illegal usage of stored alachlor. The soluble, non-soil binding nature of alachlor suggests that the June 22 rainfall event may have caused this pesticide to enter the river via surface runoff.

4.1.4.2.3.2 Metolachlor

Metolachlor accounted for 22 % of the pesticide sales in the Yamaska River basin in 1982 (SAGE, 1988). As a herbicide, it is used with corn, soybeans, potatoes and rutabagas which together constitute 38.8% of the crops grown in this area. These figures indicate a substantial use of this herbicide in this basin which seems to be reflected in the low but regular detections.

Metolachlor is applied to the fields in late April (for corn) and in mid to late May (for beans) (Appendix 6). As shown in Table 6, metolachlor was detected in late June and early July of 1987 and in late May and all of June in 1988. Metolachlor was also detected in some of the tributaries of the Yamaska river in late June 1988. In 1987, the detections occurred during or after precipitation events, whereas, in 1988 the first two detections (May 24, June 7) were found in dry parts of the season while that on July 28 followed a precipitation event. In the tributaries of the Yamaska River, the detections followed rainfall events. Metolachlor was detected at sites A1 and A2 of the St. Regis River on the June 23 sampling date probably due to the June 22 rainfall event. Metolachlor was also detected on the July 12 sampling dates at the mouth and site A1 of the Tortue River. This detection may have been due to the two small precipitation events which immediately preceded this date (Figure 6c).

Metolachlor is non-ionic, moderately soluble and has a low Koc value (Table 9), thus indicating an association with the water compartment as found in the results. According to Buttle (1989), however, metolachlor concentrations on sediment are consistently greater than those in solution, sometimes by 21 times.

Metolachlor persists for three to five months in soil and has the potential to contaminate groundwater (McRae, 1989; Maltais, 1987). Furthermore, the detections may have been due, in part, to residues persisting for the length of the sampling season.

4.1.4.2.4 Triazines

4.1.4.2.4.1 Atrazine

Atrazine makes up 53.4 % of the pesticide sales in the St. Francois River Basin. Only 4.7% of this areas crops were corn, the crop upon which atrazine is used (SAGE, 1988). As already mentioned in earlier sections atrazine is basic and soluble and would, therefore, be found in the water compartment as is apparent in our results. Early July and August are characterized by high precipitation (Aubin, personal communication, 1989), which correspond to the peaks of atrazine concentration in these rivers. In 1988, the detections were in the tributaries of the St. Francois River on the May 31 sampling date. Again these detections follow major precipitation events (Aubin, personal

communication, 1989). Atrazine was also detected in the St. Jacques River, with a maximum concentration of 11.3 ug L^{-1} on the July 14, 1988 sampling date. This sampling date was preceded by small rainfall events.

According to SAGE (1988), atrazine is utilized extensively in both the Yamaska and Assomption River basins. Our results, however, indicated that atrazine surpasses the guidelines only in the Yamaska River. The absence of this herbicide in the Assomption River could be due to a number of differing physical parameters particular to the individual river basins, such as the soil and sediment type, the water acidity and alkalinity etc. Further studies are being undertaken by ourselves to elucidate this point.

4.1.4.2.5 Organophosphates

4.1.2.5.1 Diazinon

The insecticide diazinon accounted for 0.3 % of the pesticide sales in 1982 in the Yamaska River basin (SAGE, 1988). Diazinon is used on a wide variety of crops including tobacco, beans, fruit, carrots, cucumbers, lettuce, onions and tomatoes which represent 1.3% of the crops grown in the Yamaska basin (SAGE, 1988). These sales and usage data suggest a relatively small use of this pesticide which is supported by results. Diazinon was

also found in the St. Jacques River, although sales data were not available.

Diazinon, a phosphate pesticide, is soluble and has a moderate particle affinity (Table 9). Taken together, these characteristics may suggest that the diazinon was present in both water and sediment phases, although in the Yamaska River Basin it was found only in the water compartment (Table 6).

Diazinon is applied from late May to mid June (Appendix 6). Detections were made on May 17 implying that that diazinon may not have been applied to the fields by this time. Since diazinon persists for 6 months to 1 year it is possible that the levels found were due to existing residues washed into the water from the spring snow-melt. In the St. Jacques River, diazinon was found on all three sampling dates, the maximum being detected on July 14 (Table 6). This high level coincided with a small rainfall event in the area (Figure 6c).

Diazinon has a high potential for leaching to groundwater (McRae, 1989). Since some areas of the Yamaska River Basin are susceptible to leaching and diazinon has a long persistence one would expect to find some of this insecticide in the groundwater.

4.1.4.2.6 Organochlorines

4.1.4.2.6.1 Hexachlorobenzene

According to Agriculture Canada (1987), hexachlorobenzene is not sold in Quebec as a pesticide. It is presumed, therefore, that the detection in the St. Regis sediment (Table 7) was due to industrial contamination.

4.1.4.2.6.2 DDE, DDD and DDT

Concentrations of p,p'-DDE found in fish collected from the Yamaska and St. Francois River mouths (Table 8) were well below the maximum permissible tissue concentration. The Canadian guidelines follow the U.S. EPA (1980a), recommendations which are set at 0.15 ug g^{-1}. DDE, a metabolite of DDT, is a very persistent compound (Table 9). These concentrations found in the fish samples may have been due to applications years or decades earlier since DDT and DDE have a long residual lives in food chains (Ware, 1978).

There have been no sales in Canada of DDE (as an insecticide) since the early 70s (Ware, 1978). In the Assomption River only one detection was found in a water sample collected on May 24, 1987 (Table 6), a sampling date preceded by three major rains (Figure 4c). DDE is non-ionic, has a low solubility, high Koc and

is very persistent (Table 9). These qualities indicate that DDE is most likely associated with the SPM or sediments. Possibly the precipitation events caused a release of water and suspended matter from the groundwater and/or a stirring of the bottom sediment. DDT and DDE were found in both the water and the sediments of the St. Regis, St. Jacques and Tortue Rivers probably for the same reasons mentioned above. The detections were presumably heightened in these small rivers as compared to the larger rivers because of the smaller volume of water involved. DDD was also found in the SPM of the St. Jacques River (Table 7) for the same reasons.

4.1.4.2.6.3 Lindane and α- and β-BHC

Alpha-BHC (Table 6) was detected in the water samples on all sampling dates and sites in the St. Regis, St. Jacques and Tortue Rivers and on one date in the Yamaska River. Alpha BHC was also found in the suspended and bottom sediments collected from these three rivers and β-BHC was found in the sediments of the St. Regis River. Since neither α-BHC nor β-BHC are registered in Canada, it is likely that the source of contamination was due to aerial transportation from countries using the technical grade insecticide (Environment Canada, 1989).

Lindane was found in all water samples collected from the St. Regis, St. Jacques and Tortue Rivers and in the SPM from the

Tortue River (Tables 6 and 7). Lindane is registered for seed treatment of wheat, barley, oats, corn, soybean and peas. These crops are grown in the St. Regis and Tortue River basins and constituted 43.3 and 45.4% of the total crops grown in these areas in 1982, respectively (similar data was not available for the St. Jacques) (SAGE, 1988). Although incomplete, this information indicates a possible usage of lindane in this area which is supported by the results.

In contrast to the consistently low levels of α-BHC, the lindane concentrations vary from the basal levels to seven fold exceedances of the WQG in the water from the St. Regis, St. Jacques and Tortue Rivers. This seasonal variation of lindane concentration, when observed with reference to the α-BHC detections indicates more local field or livestock application.

In the St. Regis River, the lindane levels exceeded the WQG on the June 23 and Aug 15 sampling dates, while in the Tortue River the WQG was surpassed only on the July sampling date. Since each detection being preceded by a major precipitation event, the temporal differences in May could have been due to a variation in the application timing.

According to Environment Canada (1988), the transfer of lindane to the bottom sediments is slow and primarily a function of diffusion. The α isomer of BHC was detected in both the

suspended and bottom sediments of both rivers while lindane was found only in the suspended sediments of the Tortue River. Although α-BHC has a solubility and Koc value similar to lindane, it has a longer persistence and is more resistent to microbial breakdown than is lindane which may explain its predominance in the sediments (Environment Canada, 1989).

Lindane has a high potential for the contamination of groundwater (McRae, 1989). Since both lindane and α-BHC have relatively long persistences, they may have contaminated the surface waters from groundwater sources.

Lindane was also found at a relatively low concentration in the fish samples taken from the Yamaska River mouth in 1987 (0.009 ug g^{-1}). The guideline for the protection of the aquatic life is 0.01 ug g^{-1} and even if it is expected to bioconcentrate 35 to 486 times for a variety of fish species (U.S. EPA, 1980b), it may not present a problem as its depuration rates are rapid (Rodgers et al., 1983).

4.1.4.2.6.4 Chlordane

The insecticide, chlordane, represented only 0.2 % of the pesticide sales in the Yamaska River basin (SAGE, 1988). It is used on tobacco and strawberries which together make up only 0.1 % of the crops grown in the area. This insecticide was detected

in the water of the Yamaska in October 1987 and at low levels in the water and the sediment of the St. Jacques River in August 1988 (Table 6).

The temporal interval between the probable application and detection may be due to the persistent nature of chlordane. Chlordane is non-ionic, has a very low solubility, has a high Koc and is stable in water. In view of these qualities, one would expect to find chlordane in the sediment and water, although it was found only in the water in this study. Chlordane is also described as being persistent and stable in water (Weber et al., 1981; SAGE, 1988). Since chlordane was banned in 1985 with the provision to use remaining stocks, it is possible that this detection of chlordane was due to an application earlier in the year or perhaps from a previous year.

Chlordane was found in the water and sediments of the St. Regis and Tortue Rivers. For chlordane, no more than 15 % of the residues leaches to a depth greater than the cultivated layer and according to Villeneuve (1985), it is unlikely to contaminate groundwater.

4.1.4.2.6.5 Endosulfan

In the St. Regis River, α-endosulfan was detected at site A2 on the June 23 and August 15 sampling dates. In the Tortue River,

both α and β-endosulfan were detected at sites A1 and A2 on June 23 and at site A1 on August 15. Endosulfan is applied to fields in early to mid May and from mid June to late August (Appendix 6). These dates of application correspond to the above detections. Endosulfan, an organochlorine insecticide, has a very low solubility. It is possible, therefore, that this pesticide is entering the water with the SPM.

4.1.4.2.6.6 Dieldrin

The insecticide, dieldrin, is similar to DDT and DDE in that it is non-ionic, has a low solubility, high Koc and is very persistent (Table 9) indicating immobility in water. In contrast to DDT and DDE, dieldrin is still registered for use in Canada (Appendix 1). This organochlorine pesticide was detected at the mouth of the Achigan tributary of the Assomption River on June 14, 1988, a sampling date which corresponded to a relatively dry part of the season. This detection, therefore, may have been due to recent application or it may represent a long persisting contamination.

CONCLUSIONS

1) Two herbicides and five insecticides may have had an environmental impact in aquatic ecosystems for the 1987-1988 monitoring survey for the Quebec region. These are atrazine, 2,4-DP, lindane, endosulfan, diazinon, p,p'-DDE and p,p'-DDT. These were found at concentrations exceeding the guidelines for the protection of the aquatic life.

2) Atrazine in the Yamaska River, lindane in the Assomption River, atrazine, diazinon and lindane in the St. Regis and Tortue Rivers were found at levels surpassing the guidelines in more than 50% of the monitoring sites identifying these as problematic.

3) Small river monitoring, in certain cases, may reveal the sources of pesticide contamination. This was possibly the case for the A2 site of the Tortue River.

4) Several physicochemical parameters influenced the dispersal in aquatic systems of pesticides that have some affinity for water (eg. atrazine and diazinon). The precipitation, hence the flow of rivers, were directly related to the pesticide concentrations found in surface waters.

5) In basins where atrazine is widely used, it is suggested that the physical and chemical components of the ecosystem determine

the rate at which atrazine enters aquatic systems. This was the case for the Yamaska and Assomption Rivers as atrazine was omnipresent in the former river and not in the latter.

6) Organochlorine pesticides were found in both suspended particulate material (SPM) and bottom sediments confirming their relative persistency as compared to other current "in use" pesticides. Atrazine, a widely used, "in use" pesticide, was detected in SPM and bottom sediments of the Yamaska River.

7) The concentrations of pesticides found in fish were well below the maximum permissible tissue concentrations.

RECOMMENDATIONS

It is recommended that: 1) future monitoring efforts by the Hydrology and Networks section of the Centre Saint-Laurent be concentrated on pesticides that have been identified as problematic in Quebec rivers draining agricultural basins. In addition, efforts should be initiated to identify other "in use" pesticides which have the potential to affect water quality (ie reconnaissance sampling).

2) future sampling programs should involve adequate replication so that the final results will be statistically sound.

3) a thorough understanding of the possible pesticide routes of entry into surface waters be obtained which will enable the establishment of sounder and more cost effective monitoring and surveillance programs. Future investigations should identify and monitor the presence of pesticides in groundwater, precipitation, and soil as well as in surface waters and sediment.

4) monitoring and surveillance efforts be followed up by investigations looking into the bioeffects pesticide contaminants may have on the aquatic systems. Furthermore, these should discern between the effects evoked by the different contaminating factors.

5) on a five year basis, a report comparable to the SAGE report on the principal pesticides in usage for the Quebec Region be updated.

6) a through study of pesticide use in the river basins should be carried out, possibly through a survey of pesticide usage in the areas.

7) to communicate with other regulatory authorities to properly define respective roles in pesticide management (including the exploration of legislative authority with regard to pesticide use) and to set up definite goals for the reductions of exceedances.

8) take a more active role in promoting the development of alternative pest control strategies

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6.0 APPENDICES

Appendix 1: Pesticides analyzed for in water and fish samples (adapted from Agriculture Canada, personal communication, 1989; CCREM, 1987; CCREM Draft, 1988, Environment Canada, 1979, Environment Canada, 1980)

Pesticides	WQG ug/L	WQG Reference	Status of pesticide
Carbamates			
Aldicarb	NA	NA	Registered
Butylate	NA	NA	Registered
Carbofuran	2.0000	Canadian Water Quality Draft 1988	Registered
Phenoxyacids			
2,4-DP	4.0000	Canadian Water Quality Guidelines 1987	Registered
2,4-D	4.0000	Canadian Water Quality Guidelines 1987	Registered
2,4,5-TP	4.0000	Canadian Water Quality Guidelines 1987	Not registered
2,4,5-T	4.0000	Canadian Water Quality Guidelines 1987	Discontinued 1985
Picloram	29.0000	Canadian Water Quality Draft 1988	Registered
Amides			
Alachlor	NA	NA	Banned 1985
Metolachlor	78.0000	Canadian Water Quality Draft 1988	Registered
Triazines			
Atrazine	2.0000	Canadian Water Quality Draft 1988	Registered
Metribuzin	NA	NA	Registered
Organophosphates			
Diazinon	0.0800	Environnement Canada 1980	Registered
Methyl Parathion	NA	NA	
Fenetrothion	NA	NA	Registered
Parathion	0.0080	Environnement Canada 1980	Registered
Organochlorines			
Hexachlorobenzene	0.0065	Canadian Water Quality Guidelines 1987	Discontinued 1976
Heptachlor	0.0100	Canadian Water Quality Guidelines 1987	Discontinued 1987
Aldrin	0.0040	Canadian Water Quality Guidelines 1987	Registered
P,P'-DDE	0.0030	Environnement Canada 1980	Not registered
MIREX	0.0010	Environnement Canada 1980	Not registered
a-BHC	0.0100	Canadian Water Quality Guidelines 1987	NA
Lindane	0.0100	Canadian Water Quality Guidelines 1987	Registered
b-BHC	0.0100	Canadian Water Quality Guidelines 1987	NA
Heptachlor epoxide	0.0100	Canadian Water Quality Guidelines 1987	Registered
cis-chlordane	0.0060	Canadian Water Quality Guidelines 1987	Registered
trans-chlordane	0.0060	Canadian Water Quality Guidelines 1987	Registered
o,p-DDD	0.0010	Canadian Water Quality Guidelines 1987	Discontinued 1985
o,p-DDT	0.0010	Canadian Water Quality Guidelines 1987	Discontinued 1985
p,p'-DDD	0.0010	Canadian Water Quality Guidelines 1987	Discontinued 1985
p,p'-DDT	0.0010	Canadian Water Quality Guidelines 1987	Discontinued 1985
Methoxychlor	0.0300	Environment Canada 1979	Registered
a-endosulfan	0.0200	Canadian Water Quality Guidelines 1987	Registered
Dieldrin	0.0040	Canadian Water Quality Guidelines 1987	Registered
Endrin	0.0023	Canadian Water Quality Guidelines 1987	Registered
b-endosulfan	0.0200	Canadian Water Quality Guidelines 1987	Registered
In 1988 only			
Organophosphates			
Malathion	0.1000	Environnement Canada 1980	Registered
Phorate	NA	NA	Registered
Phenoxyacids			
MCPA	NA	NA	Registered

'NA' means 'not available'
WQG Water Quality Guideline

Appendix 2: List of pesticides analyzed for in suspended and bottom sediment and in resin column samples

Organochlorines:

hexachlorobenzene
heptachlor
aldrin
p,p'-DDE
mirex
α-BHC
lindane
β-BHC
heptachlorepoxide
cis-chlordane
trans-chlordane
o,p'-DDD
o,p'-DDT
p,p'-DDD
p,p'-DDT
methoxychlor
a-endosulfan
dieldrin
endrin
β-endosulfan

Organophosphates:

diazinon
methyl parathion
malathion
fenitrothion
parathion

Triazine herbicides:

atrazine
metribuzine

Carbamates:

aldicarb
butylate
carbofuran

Amides:

alachlor
metolachlor

Phenoxyacid herbicides:

DICAMBA
2,4-DP
2,4-D
silvex
2,4,5-T
2,4-DB
MCPA

Chlorobenzenes (resin column only):

1,3- and 1,4-dichlorobenzene
1,2-dichlorobenzene
1,3,5-trichlorobenzene
1,2,4-trichlorobenzene
1,2,3-trichlorobenzene
1,2,3,5-tetrachlorobenzene
1,2,3,4-tetrachlorobenzene
pentachlorobenzene

Appendix 3: Physical and chemical parameters of water samples

Rivers and Tributaries	Date of sampling	Temperature (field) C	pH (field)	SC*(field) us/cm	OD$(field) mg/L	pH	SC*(field) us/cm	Turbidity JTU	Colour	True Colour
Yamaska	30-JUN-87	21.00	7.98	367.63	10.80	8.40	448.00	38.75	374.75	
	07-JUL-87	23.17	7.97	369.57	9.60	8.27	446.00	36.33	424.67	
	14-JUL-87	29.00	8.50	376.60	9.20	8.50	438.00	28.00	384.00	
	21-JUL-87	22.00	8.20	425.00	6.20	8.20	453.33	63.33	903.33	
	28-JUL-87	22.50	8.00	407.00	7.00	8.10	447.00	44.00	552.00	
	04-AUG-87	23.10	8.75	417.00	7.85	8.50	453.00	33.00	516.00	
	06-AUG-87					8.90	456.00	43.50	516.00	
	14-OCT-87		8.20	320.00	9.80	7.77	305.67	26.00	287.33	
Saint Francois	30-JUN-87	20.38	7.23	124.50	10.20	7.80	161.00	23.00	228.50	
	07-JUL-87	25.00	7.90	143.70	9.40	8.00	175.00	7.50	266.00	
	14-JUL-87	29.00	8.00	151.60	7.20	7.90	177.00	7.63	162.00	
	21-JUL-87	23.00	7.80	228.00	8.20	7.90	212.00	7.50	150.00	
	28-JUL-87	21.17	7.50	195.67	8.43	7.87	222.33	7.57	144.00	
	04-AUG-87	23.10	7.85	219.75	8.03	7.83	214.00	7.83	144.00	
	06-AUG-87					7.90	210.00	7.30	190.00	
	14-OCT-87	10.00	8.00	152.00	11.20	7.40	143.00	6.00	114.00	
Yamaska	11-MAY-88	16.00	8.70		8.80	8.70	357.00	19.00	215.00	
	17-MAY-88	13.00	8.10	373.00	9.20	8.20	388.00	23.50	291.00	
	24-MAY-88	20.00	9.10	373.00	12.40	9.00	384.00	0.50	128.00	
	07-JUN-88	19.50	8.20	395.80	11.40	8.30	393.00	24.00	272.00	
	21-JUN-88	23.00	7.50	455.20	10.40	8.10	453.00	47.00	574.00	
	28-JUN-88	17.50	7.80	474.60	6.30	8.10	503.33	83.33	993.00	
Yamaska Tributaries										
South	17-MAY-88	13.00	7.80	360.00		8.00	334.00	15.00	182.00	
	28-JUN-88	19.00	7.70	448.00	4.00	8.00	499.00	9.60	150.00	
Chibouet	17-MAY-88	11.50	8.30	606.00		8.20	632.00	12.00	174.00	
	28-JUN-88	17.50	8.20	671.50	4.20	8.20	761.00	9.80	158.00	
David	17-MAY-88	11.00	8.40	521.00		8.30	514.00	14.00	174.00	
	28-JUN-88	18.00	8.30	389.30	6.80	8.40	569.00	29.00	534.00	
Saint Francois	11-MAY-88	16.00	8.70		9.70	8.70	180.00	4.50	104.00	
	24-MAY-88	19.50	8.20	213.00	7.40	7.90	205.00	4.70	72.00	
	31-MAY-88	20.00	7.70	219.40	7.20	7.90	206.00	4.70	92.00	
	07-JUN-88	19.70	8.10	220.80	7.90	8.20	220.00	8.30	136.00	
	21-JUN-88	28.50	8.10	227.40	7.00	8.30	245.00	8.30	158.00	
Saint Francois Tributaries										
Saint Germain	31-MAY-88	22.00	8.40	316.30	9.00	8.10	311.00	12.00	240.00	
Aux Vaches	31-MAY-88	21.00	8.40	430.00	10.40	8.50	441.00	7.00	172.00	
Assomption	10-MAY-88	12.00	7.90	103.00		7.50	96.30	9.70	183.00	
	25-MAY-88	17.00	8.00	105.00	7.40	7.40	107.00	7.20	64.00	
	08-JUN-88	17.00	7.90	143.40	12.80	7.50	140.00	5.70	75.00	
	14-JUN-88	21.50	8.20	542.90	6.40	7.70	161.00	5.10	74.00	

* Specific Conductivity
$ Optical Density

(Appendix 3 continued)

Rivers and Tributaries	SPM (105 C)	SPM (550 C)	Alcalinity mg/L CaCO3	Hardness mg/L CaCO3	Theor.Cond. us/cm	Calcul.Hard. mg/l CaCO3	Sum Anions meq/L	Sum Cations meq/L	Ionic Balance %	NO2-NO3 mg/L
Yamaska	59.00		121.33	151.43	450.00	148.10	4.18	4.20	0.20	1.89
	38.67	32.67	136.90	165.40	454.33	159.63	4.33	4.30	-0.40	2.29
	28.00		136.00	169.00	481.00	166.40	4.36	4.64	3.10	1.18
	49.00		123.50	147.63	467.00	145.03	4.24	4.38	0.77	0.40
	38.00	31.00	105.40	130.40	435.00	129.80	3.82	4.03	2.70	0.04
	37.00		101.20	125.50	433.00	119.70	3.87	3.85	-0.40	0.04
	37.00		102.10	125.50	439.00	119.10	3.91	3.94	0.40	0.01
	67.00		68.03		331.33	96.33	2.87	3.00	2.27	0.89
Saint Francois	34.00		48.83	60.03	156.50	59.48	1.47	1.47	-0.86	0.36
	11.00	7.00	52.50	64.80	174.00	61.70	1.64	1.60	-1.00	0.18
	11.67		51.67	65.60	176.67	63.57	1.61	1.66	1.70	0.01
	11.00		57.50	71.40	206.00	69.00	1.89	1.89	0.00	0.17
	9.67		58.63	72.43	209.00	71.43	1.90	1.95	1.33	0.12
	11.00		56.40	68.30	197.00	64.60	1.81	1.80	-0.15	0.07
	9.00		53.60	69.50	195.00	65.30	1.78	1.81	0.80	0.14
	5.00		37.70		156.00	56.20	1.36	1.43	2.40	0.17
Yamaska	25.00		90.90		387.00	128.60	3.47	3.57	1.40	1.49
	32.00		106.40	153.70	422.00	135.80	3.86	3.87	0.10	1.28
	26.00		99.20	138.60	394.00	135.40	3.73	3.33	-5.70	0.68
	26.00		101.20	129.50	378.00	126.80	3.21	3.81	8.50	0.06
	44.00		113.50	146.50	493.00	141.00	4.35	4.47	1.30	0.12
	85.00		118.47	145.73	553.67	144.80	4.87	4.95	0.87	0.27
Yamaska Tributaries South	26.00		71.20	102.30	352.00	94.50	3.11	3.14	0.40	0.90
	14.00		96.60	127.30	518.00	123.90	4.45	4.64	2.10	0.66
Chibouet	17.00		192.00	318.60	750.00	284.00	6.80	6.80	0.00	2.17
	11.00		230.80	294.10	850.00	282.10	7.67	7.88	1.30	0.02
David	16.00		201.80	252.00	594.00	222.30	5.74	5.61	-1.10	0.54
	33.00		203.00	219.60	625.00	211.90	5.90	5.96	0.60	0.01
Saint Francois	10.00		50.90		193.00	65.10	1.74	1.77	0.90	0.05
	9.00		55.60	74.70	216.00	71.10	1.93	1.98	1.20	
	9.00		57.20	72.00	223.00	66.90	2.02	2.02	0.00	0.04
	15.00		60.90	72.70	232.00	70.10	2.11	2.10	-0.02	
	14.00		63.10	75.60	265.00	73.00	2.36	2.45	1.10	0.03
Saint Francois Tributaries Saint Germain	14.00		99.30	137.70	340.00	129.20	3.12	3.13	0.20	0.41
Aux Vaches	8.00		148.40	174.90	504.00	184.20	4.92	4.92	4.30	0.10
Assomption	13.00		19.80		104.00	31.50	0.92	0.90	-1.30	0.41
	7.00		20.30	33.20	110.00	31.80	0.95	0.95	0.10	0.16
	5.00		30.40	42.40	144.00	41.00	1.27	1.27	0.10	0.16
	5.00		35.80	49.70	164.00	46.50	1.45	1.46	0.30	0.04

* Specific Conductivity
§ Optical Density

(Appendix 3 continued)

Rivers and Tributaries	Total P mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SO4 mg/L	Cl mg/L	Tot.Org.C mg/L	Diss. C mg/L	Organic C Partic. mg/L
Yamaska	0.14	40.53	11.40	25.80	4.37	31.80	33.05	8.15	7.83	0.32
	0.12	42.07	13.27	22.47	5.09	30.40	29.40	8.80	8.57	0.24
	0.09	45.70	12.70	28.00	3.68	30.80	32.40	7.50	7.20	0.30
	0.30	39.57	11.23	29.17	5.30	31.13	38.00	7.50	7.20	0.29
	0.34	36.50	9.40	30.40	4.56	26.60	41.00	7.60	7.30	0.30
	0.35	34.10	8.40	30.90	4.51	28.40	44.80	7.60	7.20	0.37
	0.41	33.70	8.50	33.30	4.36	28.00	45.60	7.60	7.40	0.16
	0.21	29.77	5.33	22.40	4.05	29.73	29.33			
Saint Francois	0.11	17.80	3.65	5.45	1.69	10.95	8.55	8.33	8.08	0.25
	0.07	18.60	3.70	7.90	1.09	12.90	10.90	9.00	8.80	0.17
	0.05	18.80	4.03	8.43	0.99	11.97	11.53	6.70	6.50	0.20
	0.06	20.20	4.50	11.10	1.32	14.90	15.00	6.60	6.40	0.18
	0.06	21.13	4.53	11.17	1.39	14.77	14.53	6.27	6.07	0.22
	0.06	18.65	4.38	11.10	1.13	15.03	14.30	6.35	6.15	0.20
	0.06	18.90	4.40	10.90	1.10	19.20	13.50	6.50	6.30	0.21
	0.06	16.40	3.70	6.40	1.08	16.60	8.90	8.80		
Yamaska	0.16	35.20	9.90	21.30	2.78	32.00	31.20		6.20	
	0.20	36.40	10.90	24.40	3.58	33.20	33.60		6.00	
	0.20	38.40	9.60	12.20	3.46	33.80	35.20		7.20	
	0.30	35.80	9.10	27.40	3.34	4.70	38.60		7.30	
	0.42	39.50	10.30	35.30	4.57	33.60	48.80		7.70	
	0.48	40.40	10.67	43.83	5.93	37.20	60.53		8.00	
Yamaska Tributaries South	0.20	28.30	5.80	27.00	2.81	26.40	38.00		6.00	
	0.30	36.60	7.90	47.20	4.30	36.80	60.40		7.70	
Chibouot	0.21	82.40	19.00	22.00	6.40	90.80	32.40			
	0.51	79.00	20.60	46.80	8.00	61.40	63.20		14.10	
David	0.10	57.20	19.30	24.40	4.09	46.60	24.80		7.90	
	0.29	57.00	16.90	37.00	4.58	40.40	34.00		8.90	
Saint Francois	0.05	19.00	3.80	10.20	1.08	15.40	14.10		6.30	
	0.06	21.40	4.30	12.00	1.32	16.70	16.60		6.20	
	0.05	20.20	4.00	14.90	1.45	17.70	18.00		6.20	
	0.06	21.00	4.30	15.30	1.35	18.20	18.30		6.40	
	0.08	21.80	4.50	20.80	1.69	22.40	22.20		7.20	
Saint Francois Tributaries Saint Germain		41.70	6.10	11.30	2.30	32.60	15.20		11.10	
Aux Vaches	0.13	45.60	17.10	26.40	3.66	32.60	30.70		11.30	
Assomption	0.07	9.00	2.20	5.70	0.76	11.90	8.80		4.30	
	0.05	9.10	2.20	6.80	0.85	10.50	11.20		4.10	
	0.06	11.80	2.80	9.80	0.97	12.50	13.80		4.60	
	0.07	13.50	3.10	11.40	1.23	13.10	16.20		4.80	

* Specific Conductivity
$ Optical Density

(Appendix 3 continued)

Rivers and Tributaries	Date of sampling	Temperature (field) C	pH (field)	SC*(field) us/cm	OD$(field) mg/L	pH	SC*(field) us/cm	Turbidity JTU	Colour	True Colour
	22-JUN-88	23.00	8.20	206.90	8.40	8.00	205.00	6.60	91.00	
Assomption										
Tributaries										
Ouareu	14-JUN-88	23.00	7.50	113.80	6.20	7.60	112.00	12.00	87.00	
Achigan	14-JUN-88	21.50	9.20	404.50	7.20	8.50	433.00	20.00	201.00	
Saint Regis										
A1	23-JUN-88	20.00	8.30		9.90	8.40	1190.00	13.00	124.00	
A2	23-JUN-88	20.50	7.70		1.60	7.90	1610.00	28.00	946.00	
mouth	23-JUN-88	19.50	7.90		5.80	8.20	822.00	9.20	116.00	
A1	13-JUL-88	23.50	9.60	1030.00	9.40	9.50	1017.00	2.50	44.00	
A2	13-JUL-88	27.50	6.40	990.00	13.80	9.10	1222.00	1.70	34.00	
mouth	13-JUL-88	27.00	8.80	919.00	17.40	8.50	907.00	3.40	51.00	
dissolved	13-JUL-88					8.50	915.00	1.50	29.00	
A1	15-AUG-88	25.90	8.10	499.40	7.40	8.10	839.00	22.00	312.00	
A2	15-AUG-88	24.50	8.10	805.60	7.00	8.20	745.00	16.00		206.00
mouth	15-AUG-88	25.00	8.30	700.00	8.10	8.30	855.00	28.00	390.00	
Saint Jacques										
mouth	23-JUN-88	22.00	7.60		3.60	7.90	821.00	44.00	356.00	
mouth	14-JUL-88	24.00	7.70	914.00	6.40	7.70	906.00	19.00	256.00	
dissolved	14-JUL-88					8.00	901.00	3.10	42.00	
mouth	15-AUG-88	22.00	7.60	622.00	2.20	7.80	685.00	32.00	355.00	
Yurtus										
A1	23-JUN-88	20.50	7.90		3.60	8.20	702.00	79.50	1000.00	
A2	23-JUN-88	19.00	7.40		3.60	7.80	559.00	88.00	1000.00	
mouth	23-JUN-88	18.00	7.70		6.00	7.90	530.00	47.00	492.00	
A1	12-JUL-88	29.00	9.30	753.30	9.40	8.30	592.00	11.00	122.00	
A2	12-JUL-88	26.50	8.80	877.60	11.20	9.30	701.00	4.30	89.00	
mouth	12-JUL-88	25.00	8.70	660.00	6.00	8.40	628.00	9.70	136.00	
dissolved	12-JUL-88					8.70	1059.00	4.20	72.00	
A1	15-AUG-88	24.00	7.80	508.00	5.40	7.90	547.00	53.00	780.00	
mouth	15-AUG-88	25.00	8.30	649.20	7.40	8.40	1040.00	14.00	213.00	

* Specific Conductivity
$ Optical Density

(Appendix 3 continued)

Rivers and Tributaries	SPM (105 C)	SPM (550 C)	Alcalinity mg/L CaCO3	Hardness mg/L CaCO3	Theor.Cond. us/cm	Calcul.Hard. mg/l CaCO3	Sum Anions meq/L	Sum Cations meq/L	Ionic Balance %	NO2-NO3 mg/L
	10.00		44.30	57.40	211.00	55.20	1.87	1.85	-0.50	
Assomption Tributaries										
Ouarou	6.00		22.10	31.00	112.00	29.20	0.97	0.98	0.50	0.04
Achigan	25.00		54.40	108.40	460.00	103.40	3.78	3.92	1.90	0.06
Saint Regis										
A1	9.00		206.50	388.10	1576.00	501.00	12.13	14.63	9.40	0.03
A2	48.00		362.50	453.90	1817.00	438.00	15.98	15.37	-1.90	0.01
mouth	5.00		147.40	231.70	951.00	228.80	8.08	8.07	-0.10	0.01
A1	2.00		110.70	387.50	1294.00	377.30	10.42	10.72	1.40	4.02
A2	1.00		198.90	488.50	1519.00	466.10	13.42	13.02	-1.50	15.80
mouth	4.00		133.40	345.70	1121.00	335.40	9.10	9.38	1.50	0.09
dissolved	1.00		134.30	344.20	1116.00	331.20	9.12	9.26	0.80	0.09
A1	17.00		144.30	298.60	969.00	290.10	8.05	8.37	1.90	2.72
A2	9.00		141.40	263.30	856.00	255.80	7.24	7.47	1.50	2.74
mouth	29.00		146.20	285.80	1019.00	300.60	8.33	8.95	3.60	2.56
Saint Jacques										
mouth	66.00		198.40	292.90	982.00	288.40	8.59	8.59	0.00	0.12
mouth	31.00		191.50	347.60	1023.00	331.70	9.15	9.21	0.40	8.20
dissolved	0.50		190.60	346.80	1019.00	332.30	9.02	9.22	0.70	8.40
mouth	36.00		119.30	282.70	780.00	203.80	6.51	6.79	2.10	1.10
Tortue										
A1	93.00		169.40	308.70	865.00	295.20	7.44	7.50	0.40	0.11
A2	95.00		112.00	244.20	678.00	238.20	5.71	5.77	0.50	1.20
mouth	63.00		129.90	192.30	595.00	189.60	5.23	5.26	0.30	0.17
A1	16.00		131.40	242.30	659.00	230.90	5.74	5.90	1.40	2.60
A2	3.00		107.40	308.30	869.00	291.90	7.06	7.21	1.00	0.27
mouth	16.00		135.30	254.40	697.00	240.70	6.09	6.19	0.80	3.08
dissolved	5.00		151.20	373.30	1331.00	356.80	10.87	10.94	0.30	1.32
A1	40.00		93.50	210.30	632.00	207.70	5.32	5.31	0.00	2.48
mouth	16.00		156.10	283.50	1284.00	311.10	10.22	11.22	4.70	0.38

* Specific Conductivity
@ Optical Density

(Appendix 3 continued)

Rivers and Tributaries	Total P mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SO4 mg/L	Cl mg/L	Tot.Org.C mg/L	Diss. C mg/L	Organic C Partic. mg/L
	0.09	16.00	3.70	17.20	0.14	16.20	23.10		5.40	
Assomption Tributaries										
Ouarou	0.05	8.90	1.70	8.70	0.66	11.30	10.30		6.20	
Achigan	0.12	29.20	7.40	41.40	2.00	15.50	83.70		5.60	
Saint Regis										
A1	0.81	79.90	43.80	99.60	11.10	219.10	121.80		9.50	
A2	3.61	103.20	43.80	116.10	61.40	191.10	168.70		63.90	
mouth	0.15	50.40	25.00	76.50	6.60	137.20	80.80		9.00	
A1	0.13	69.00	49.80	69.30	6.40	256.00	92.00		6.30	
A2	0.28	102.60	51.00	82.00	5.20	253.00	108.00		6.10	
mouth	0.07	63.60	42.90	57.00	7.60	206.00	76.00		7.10	
dissolved	0.06	63.40	42.00	56.30	7.60	206.00	76.00		7.20	
A1		72.00	26.80	48.80	17.40	150.00	65.60		8.40	
A2		71.80	18.60	48.20	10.00	127.00	56.00		6.70	
mouth		78.50	25.40	60.00	12.90	153.00	72.40		7.50	
Saint Jacques										
mouth	0.32	69.00	28.20	62.00	4.94	125.70	70.80		9.00	
mouth	0.13	74.80	35.20	55.80	6.00	142.00	63.00		5.80	
dissolved	0.07	75.40	35.00	55.80	6.00	141.00	62.00		6.00	
mouth		54.40	16.50	58.80	6.20	109.20	62.80		6.10	
Tortue										
A1	1.04	78.00	24.40	33.00	6.30	119.60	55.20		19.10	
A2	0.73	64.40	18.80	19.20	6.70	115.60	34.80		25.20	
mouth	0.19	51.20	15.00	31.80	3.26	71.20	40.40		4.90	
A1	0.10	62.80	18.00	27.30	3.81	89.50	37.60		4.70	
A2	0.23	66.80	30.40	29.00	4.50	160.50	55.20		13.30	
mouth	0.12	64.40	19.40	29.40	4.07	97.00	40.80		5.20	
dissolved	0.12	87.50	33.60	82.50	8.70	290.00	60.80		8.80	
A1		58.80	14.80	19.90	11.60	110.00	34.80		13.60	
mouth		69.20	33.60	109.80	9.00	228.00	82.40		41.10	

* Specific Conductivity
θ Optical Density

Appendix 4: Sampling dates and geographical locations for all stations from which water and sediment samples were taken

Site	Dates (water)	Location	Dates (SPM and resin column)	Location	Dates (bottom sediments)	Location
Yamaska						
	300687	46°03'02"la	160787	46°03'02"la	160787	46°03'02"la
	070787	73°56'45"lo	220787	73°56'45"lo	220787	73°56'45"lo
	140787		290787		290787	
	210787		040887			
	280787					
	040887					
	060887					
	141087					
	110588					
	170588					
	240588					
	070688					
	210688					
	280688					
Yamaska South						
	170588	72°58'55"la				
	280588	45°30'30"lo				
Yamaska Tributaries:						
Chibouet						
	170588	45°47'25"la				
	280588	72°51'15"lo				
David						
	170588	45°58'36"la				
	280588	72°53'55"lo				

(Appendix 4 continued)

St. Francois

300687	46°06'55"la	170787	46°06'55"la	170787	46°06'55"la
070787	73°54'30"lo	230787	73°54'30"lo	230787	73°54'30"lo
140787		280787		280787	
210787		050887			
280787					
040887					
060887					
141087					
110588					
240588					
310588					
070688					
210688					

St. Francois Tributaries

St. Germain	310588	45°53'55"la 72°30'00"lo
Aux Vaches	310588	46°02'15"la 72°46'30"lo

Assomption

Mouth	100588 250588 080688 140688 220688	45°45'05"la 73°28'05"lo
100	290788	45°43'04"la 73°28'08"lo
200	290788	45°44'04"la 73°28'09"lo
300	290788	45°47'02"la 73°26'07"lo

Assomption Tributaries

Ouarou	140688	45°56'30"la 73°24'55"lo

(Appendix 4 continued)

Achigan						
	140688	45°51'20"la 73°27'00"lo				
St. Regis						
mouth	230688 130788 150888	45°24'03"la 73°33'50"lo	300888	45°24'03"la 73°33'50"lo	300888	45°24'03"la 73°33'50"lo
A1	230688 130788 150888	45°22'04"la 73°36'10"lo			300888	45°23'09"la 73°33'08"lo
A2	230688 130788 150888	45°20'08"la 73°39'25"lo			300888	45°22'04"la 73°36'01"lo
St. Jacques						
Mouth	230688 140788 150888	45°25'45"la 73°28'35"lo	300888	45°25'08"la 73°28'06"lo	310788	45°25'55"la 73°29'25"lo
A1					310788	45°25'25"la 73°27'55"lo
A2					310788	45°25'03"la 73°27'07"lo
Tortue						
Mouth	230688 120788 150888	45°24'10"la 73°32'04"lo	300888	45°24'01"la 73°32'04"lo	310888	45°24'01"la 73°32'04"lo
A1	230688 120788 150888	45°22'30"la 73°32'15"lo			310888	45°23'06"la 73°31'09"lo
A2	230688 120788 150888	45°15'09"la 73°29'05"lo				45°21'45"la 73°32'02"lo

Appendix 5: Microtox Studies

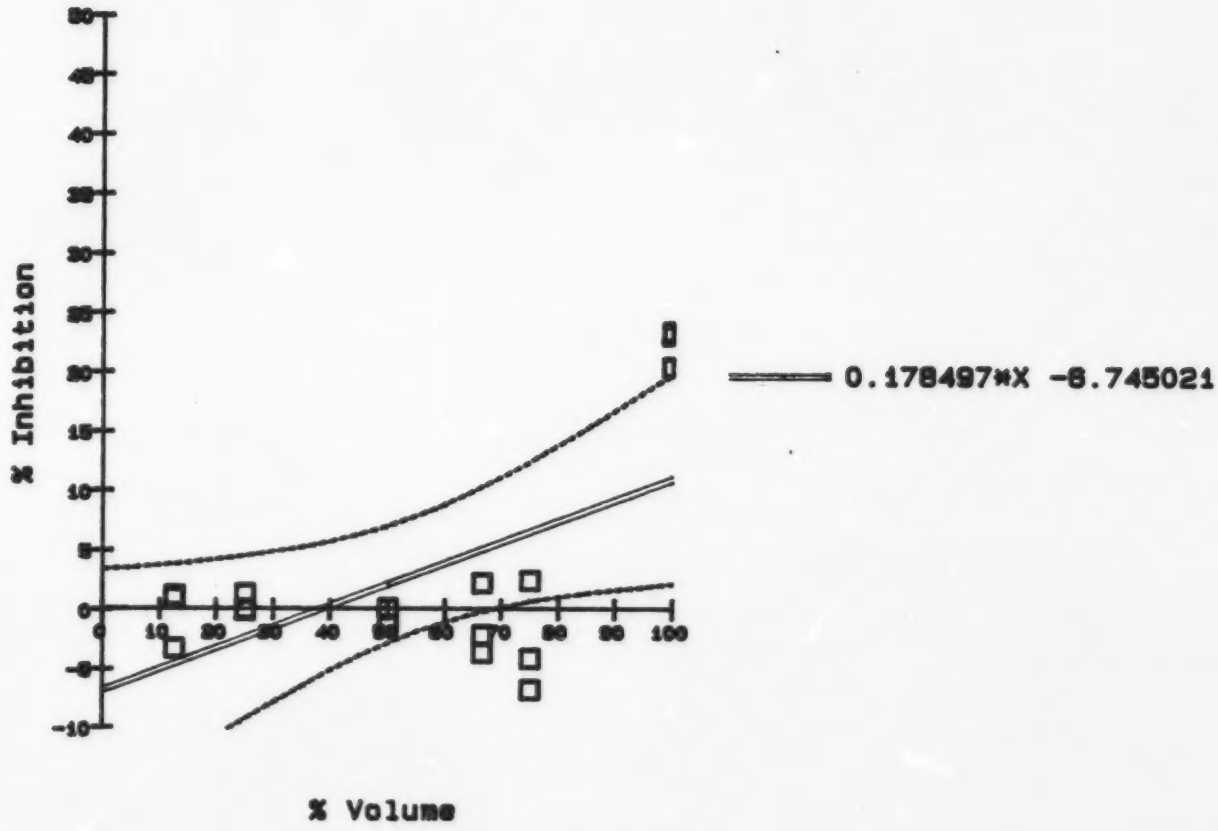
1) Sampling dates and locations for all stations for which microtox analysis was done

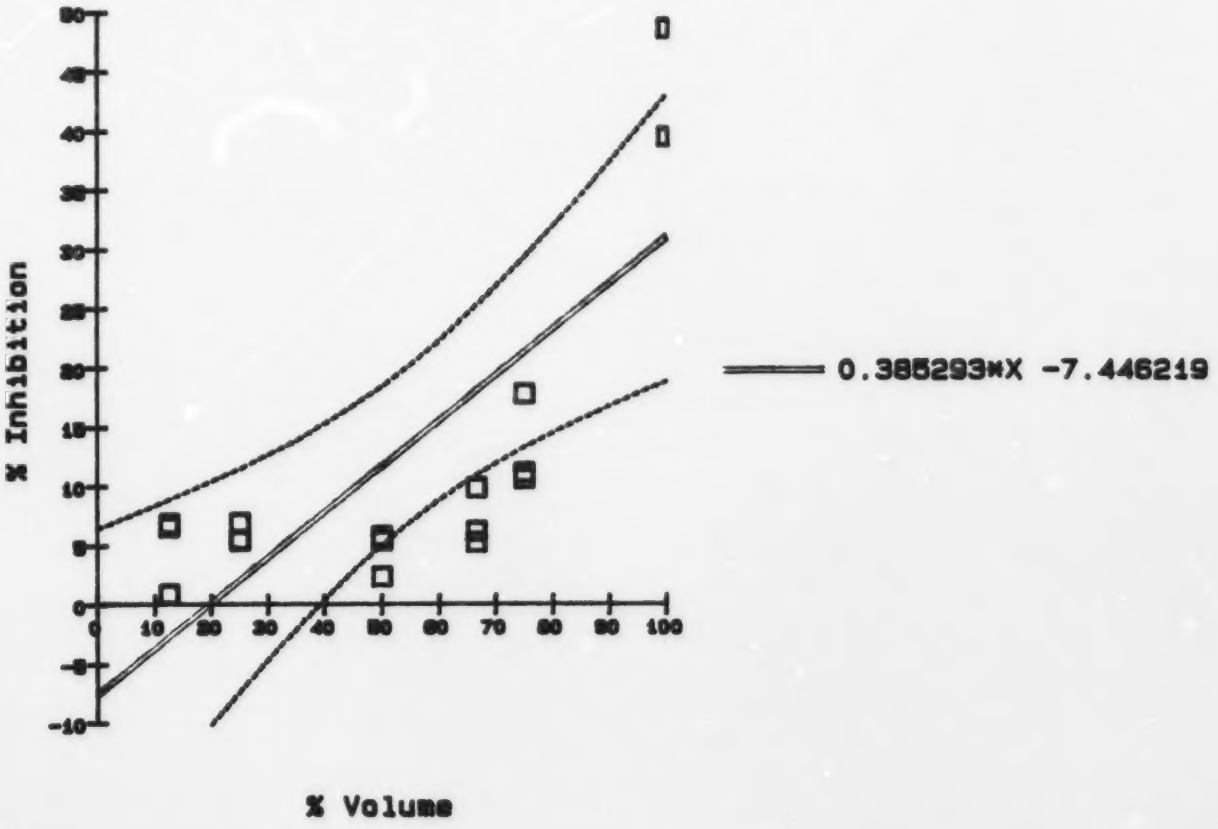
Location		Dates
Yamaska River		7 Jun 88 21 Jun 88 28 Jun 88 19 Jul 88
St. Francois River		19 Jul 88
Assomption River		14 Jul 88
St. Lawrence River	(2X)	26 Jul 88
Small Basin of La Prairie		21 Jun 88
Lake St. Pierre	(2X)	28 Jun 88 12 Jul 88
Lake St. Louis	(4X)	2 Aug 88

2) As demonstrated in Appendices 5a and 5b, the inhibition of luminescence was more intense after 15 minutes of incubation as compared to that found at 5 minutes.

Appendix 5a: Results from the Microtox toxicity assay on water from the Yamaska River sampled the 28th of June 1988 (5 min incubation)

Appendix 5b: Results from the Microtox toxicity assay on water from the Yamaska River sampled the 28th of June 1988 (15 min incubation)


% Inhibition
% Volume
0.178497*X -8.745021

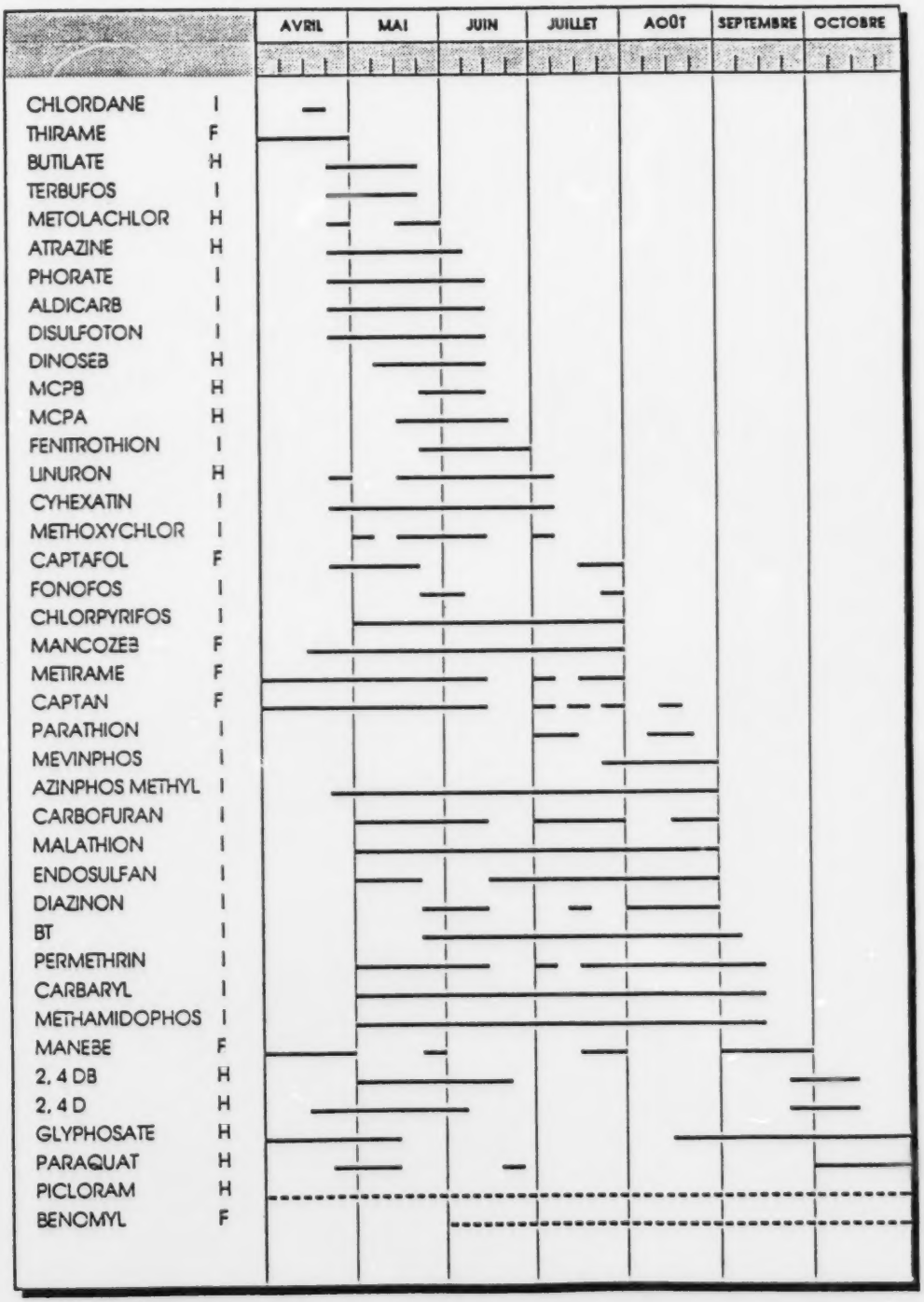

% Inhibition
% Volume
0.385293*X -7.446219

3) The Microtox test with Photobacterium phosphoreum is used to assess the acute, sublethal and chronic toxicity of a multitude of toxic substances (Ribo and Kaiser, 1987). According to Kaiser et al. (1988), the test measures the overall effect of substances and/or conditions present in a sample. Hence, the resulting data may not be correlated with any specific contaminant factor. One may need to concentrate the water sample to observe an effect as the Microtox bioassay is not a particularly sensitive test for the ecotoxicity of pesticides.

Before doing the series of dilutions necessary for a complete microtox analysis, a preset condition of 25% inhibition of bacterial luminescence was required. This was the case for only one of 16 samples given for analysis. In this sample, the 15 min inhibition was greater than the 5 min inhibition (Appendices 5a and 5b). This result is either due to an increased accumulation of the xenobiotic(s) or a degradation of the compound(s) into a more toxic metabolite (Kaiser, personal communication, 1989). This increase in toxicity with time cannot be used to differentiate between particular xenobiotic toxicities.

The microtox results could not be correlated with any specific contaminant factor in the water sample. An increased inhibition of fluorescence at 15 min was either due to an increased accumulation of fluorescence of the xenobiotic(s) or a degradation of the compound(s) into a more toxic metabolite.

Appendix 6: Periods of application of pesticides



Appendix 7: Pesticides found in XAD-2 resin column samples

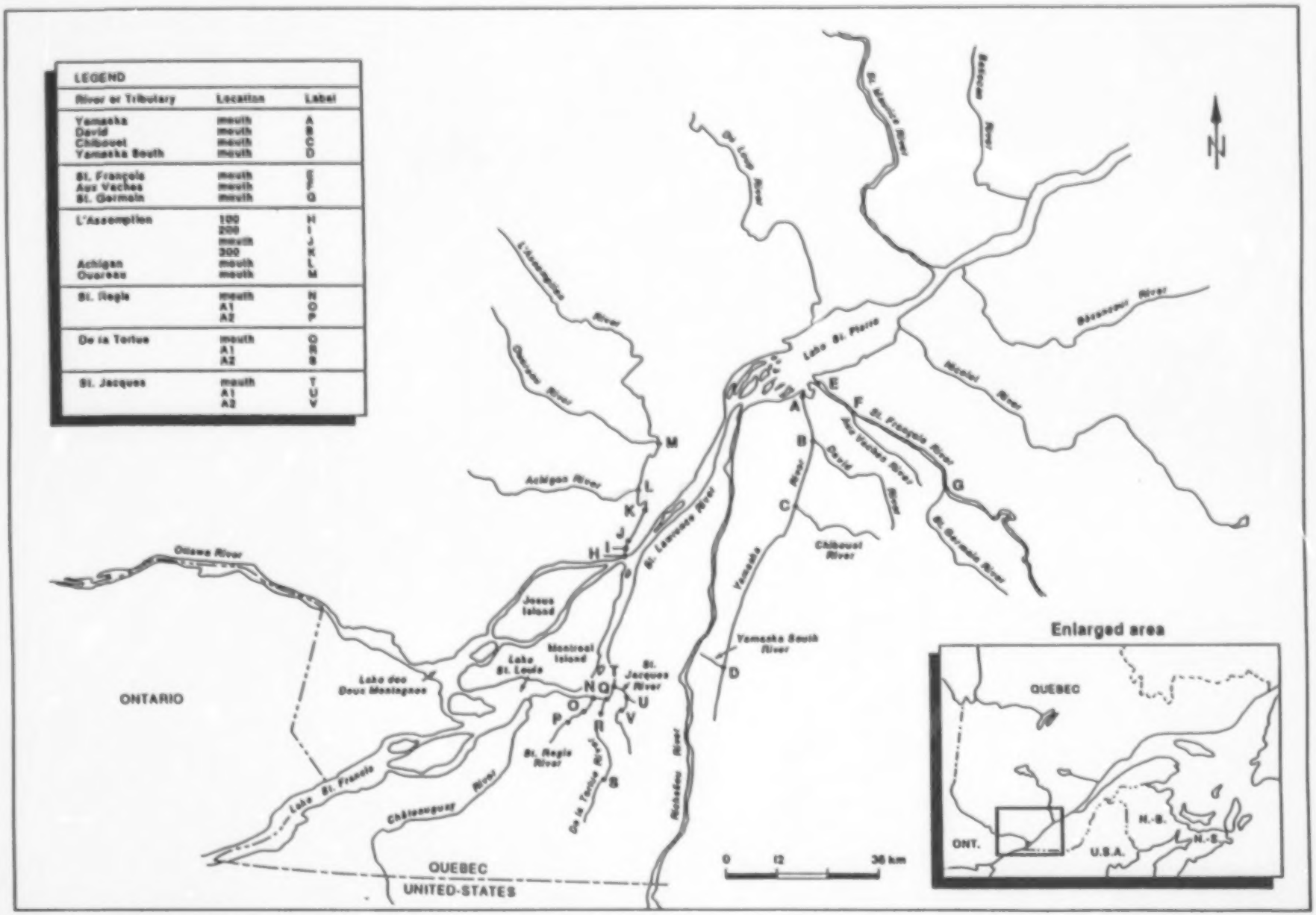
Location	Date	a-BHC ug/L	Lindane ug/L	*c chlordane ug/L	*t chlordane ug/L	o,p'-DDT ug/L	p,p'-DDD ug/L	Pentachloro-benzene ug/L	*mala./meto. ug/L	Atrazine ug/L	2,4-D ug/L
Resin Column											
Yamaska	16-JUL-87		0.0008	0.0001	0.0001	0.0001					
	22-JUL-87	0.0008	0.0009	0.0001			0.0001				
	29-JUL-87	0.0008	0.0006	0.0001			0.0001				
	04-AUG-87	0.0008	0.0006	0.0001	0.0001						
Saint Francois	17-JUL-87	0.0007	0.0003	0.0001		0.0001					
	23-JUL-87	0.0008	0.0004		0.0001						
	28-JUL-87	0.0001	0.0001								
	05-AUG-87	0.0008	0.0003								
Saint Jacques	12-JUL-88							0.00008	0.0020	0.62	0.06
Saint Regis	12-JUL-88							0.00020	0.0008	0.35	
Tortue	12-JUL-88									0.47	

*Mala./Meto. Malathion/Metolachlor
*c cis chlordane
*t trans chlordane

Appendix 8: Correlations for spacial, intersample and temporal quality control of the physical and chemical water data

Type of Quality Control	River	Date	Data correlated*	Spearman Rho Value
Spacial	Yamaska	30 Jun 87	Mean of Yam 100, 200, 300 vs Yam-in	0.997689
	Saint Francois	30 Jun 87	Mean of Sfr 100, 200, 300 vs Sfr-in	0.992665
		04 Aug 87	Mean of Sfr 100, 200, 300 vs Sfr-in	0.999465
Between replicates	Yamaska	07 Jul 87	Mean of Yam T08, T09, int vs Yam T0	1.000000
			Mean of Yam T08, T09, int vs Yam T0	1.000000
			Mean of Yam T08, T09, int vs Yam-in	0.997426
		12 Jul 87	Mean of Yam T12, T13, int vs Yam T1	0.999555
			Mean of Yam T12, T13, int vs Yam T1	1.000000
			Mean of Yam T12, T13, int vs Yam-in	1.000000
		14 Oct 87	Mean of Yam T01, T02, T03 vs Yam T0	0.998246
			Mean of Yam T01, T02, T03 vs Yam T0	1.000000
			Mean of Yam T01, T02, T03 vs Yam T0	0.989030
		28 Jun 88	Mean of Yam T01, T02, int vs Yam T0	0.998522
			Mean of Yam T01, T02, int vs Yam T0	0.992611
			Mean of Yam T01, T02, int vs Yam-in	0.998286
	Saint Francois	14 Jul 87	Mean of Sfr T10, T11, int vs Sfr T1	0.999555
			Mean of Sfr T10, T11, int vs Sfr T1	0.997906
			Mean of Sfr T10, T11, int vs Sfr-in	0.999833
		28 Jul 87	Mean of Sfr T13, T14, int vs Sfr T1	0.998880
			Mean of Sfr T13, T14, int vs Sfr T1	0.999160
			Mean of Sfr T13, T14, int vs Sfr-in	0.999936
Temporal	Yamaska	4-6 Aug 87	Yam-int vs Yam-man	0.992095
	Saint Francois	4-6 Aug 87	Sfr-int vs Sfr-man	0.974741

* Sites:
Yam = Yamaska, Sfr = Saint Francois
100, 200, 300 = 3 separate sampling sites, equally spaced across the width of the river
int = integrated sample (consisting of a mixture of the 100 series samples)
"T" series = replicates of the "int" samples
man = a sample consisting of a mixture of samples taken every hour for 24 hours



Appendix 9. **Map of station locations**

Appendix 10: Chemical Formulae of Pesticides (Worthing, 1987; Environment Canada, 1980; Sittig, 1985)

Common name	Chemical name (IUPAC)	Chemical formula
Carbamates		
Aldicarb	2-methyl-2-(methylthio)propionaldehyde o-methylcarbamoyloxime	C7H14N2O2S
Butylate	S-ethyl di-isobutylthiocarbamate	C11H23NOS
Carbofuran	2,3 dihydro-2,3-dimethyl-7-yl methylcarbamate	C12H15NO3
Phenoxyacids		
DICAMBA	3,6-dichloro-o-anisic acid	C8H6Cl2O3
2,4-DP	2-(2,4-dichlorophenoxy)propionic acid	C9H8Cl2O3
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid	C10H10Cl2O3
2,4-D	2,4-dichlorophenoxyacetic acid	C8H6Cl2O3
2,4,5-TP	2-(2,4,5-trichlorophenoxy)propionic acid	C9H7Cl3O3
2,4,5-T	2,4,5-trichlorophenoxyacetic acid	C8H5Cl3O3
Picloram	4-amino-3,5,6-trichloropyridine-2-carboxylic acid	C6H3Cl3N2O2
MCPA	4-chloro-o-tolyloxyacetic acid	C9H9ClO3
Amides		
Alachlor	2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide	C14H20ClNO2
Metolachlor	2-chloro-6'-ethyl-N-(2 methoxy-1-methylethyl)acet-o-toluidide	C15H22ClNO2
Triazines		
Atrazine	2-chloro-4-ethylamino-6-(isopropyl-amino-1,3,5-triazine	C8H14ClN5
Metribuzine	4-amino-6-tert-butyl-3-(methylthio)-1,2,4-triazin-5-one	C8H14N4OS
Organophosphates		
Diazinon	O,O-diethyl O-2-isopropyl-6-methylpyrimidin-4-yl phosphorothioate	C12H21N2O3PS
Methyl Parathion	O,O-dimethyl O-4-nitrophenyl phosphorothioate	C8H10NO5PS
Fenitrothion	O,O-dimethyl O-(3-methyl-4-nitrophenyl) phosphorothioate	C9H12NO5PS
Parathion	O,O-diethyl O-4-nitrophenyl phosphorothioate	C10H14NO5PS
Malathion	diethyl (dimethoxyphosphinothioylthio)succinate	C10H19O6PS2
Phorate	O,O-diethyl S-ethylthiomethyl phosphorodithioate	C7H17O2PS3
Organochlorines		
Hexachlorobenzene	hexachlorobenzene	C6Cl6
Heptachlor	1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene	C10H5Cl7
Aldrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphtalene	C12H8Cl6
p,p'-DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene	C14H8Cl4
MIREX	dodecachlorupentacyclodo c-ene	C10Cl12
a-BHC	1,2,4/3,5,6-hexachlorocyclohexane	C6H6Cl6
Lindane(gamma-BHC)	1,2,3,5/4,6-hexachlorocyclohexane	C6H6Cl6
b-BHC	1,3,5/2,4,6-hexachlorocyclohexane	C6H6Cl6
Heptachlor epoxide	1,4,5,6,7,8,8-heptachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindan	C10H5Cl7
cis-chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	C10H6Cl8
trans-chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	C10H6Cl8
o,p-DDD	bis(4-chlorophenyl)disulfide	C12H8Cl2S2
o,p-DDT	1,1,1-trichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl)ethane	C14H9Cl5
p,p'-DDD	bis(4-chlorophenyl)disulfide	C12H8Cl2S2
p,p'-DDT	1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane	C14H9Cl5
Methoxychlor	1,1,1-trichloro-2,2-bis(p-methoxyphenyl)ethane	C16H15Cl3O2
a-endosulfan	(1,4,5,6,7,7-hexachloro-8,9,10-trinorborn-5-en-2,3-ylenebismethylene)sulphite	C9H6Cl6O3S
Dieldrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphtalene	C12H8Cl6O
Endrin	1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydr0-6,7-epoxy-1,4:5,8-dimethanonaphtalene	C12H8Cl6O
b-endosulfan	(1,4,5,6,7,7-hexachloro-8,9,10-trinorborn-5-en-2,3-ylenebismethylene)sulphite	C9H6Cl6O3S
Chlorobenzenes		
Dichlorobenzene	dichlorobenzene	C6H4Cl2
Trichlorobenzene	trichlorobenzene	C6H3Cl3
Tetrachlorobenzene	tetrachlorobenzene	C6H2Cl4
Pentachlorobenzene	pentachlorobenzene	C6HCl5

"NA" means "not available"
WQG Water Quality Guideline